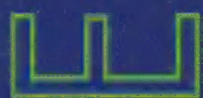# COMPRESSED EARTH BLOCKS

testing procedures

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**Compressed earth blocks :
testing procedures**

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The Centre for the Development of Enterprise (CDE), over its twenty years of operation, has built up a significant body of technical and commercial knowledge at the service of launching, developing and rehabilitating small and medium-sized enterprises in ACP countries (Africa, Caribbean, Pacific). It has done so particularly thanks to setting up sustainable partnerships with European Union enterprises.

In publishing its "Practical Guides" series, the CDE is responding to a need clearly expressed by ACP promoters and by EU entrepreneurs wishing to set up an industrial collaboration with these countries. These guides aim to enable them to adapt to the technical, commercial, financial, administrative and legal environment proper to different local contexts. Intended to make their task easier – in simple and practical terms - in a given field or in precise areas of their activities, they aim above all to be an efficient tool at the service of the manager.

In preparing these documents, the CDE turns to consultants, researchers and practitioners – both from ACP countries and from the European Union – who have a wide experience of the subject in question, and of the practical problems entrepreneurs actually encounter and of the solutions to be applied. When circumstances allow, the CDE works jointly with a co-editor (consultancy group, research organisation, specialised institution etc.) in order to ensure that the guides are distributed as widely as possible.

This document has been prepared in collaboration with the geomaterials laboratory of the Department of Civil Engineering and Building (LGM-DGCB) – URA of the French National Centre for Scientific Research (CNRS) n° 1652 of the National Engineering Institute for Public Works of Lyon (ENTPE), with CRATerre-EAG (the International Centre for Earth Construction – School of Architecture of Grenoble) with the support of ARSO (the African Regional Organization for Standardization).

The information contained in this guide is provided in good faith by the CDE, ENTPE, CRATerre-EAG, experts and consultants. They cannot, however, be held responsible for any errors, inaccuracies, deficiencies or possible omissions or for their consequences.

1.1. Compressed Earth Block technology

Building using unfired earth has existed since the most ancient times, witness the traditional housing in many parts of the planet. Today, this is the subject of renewed interest in both developing and industrialised countries. A very wide range of production techniques is developing and these are the object of detailed scientific research: compressed earth block technology is a prime example of this.

In the past, compressed earth blocks were produced by manual tamping in a wooden mould. In the 18th century, a Frenchman named François Cointeraux invented the first press, the "*Crécise*". But it was not until the beginning of the 20th century that the principle of mechanical compression was taken up again, firstly with manual presses fitted with a heavy lid which was pushed firmly down onto the surplus earth in the mould. These machines were later motorised. Equipment manufacturers also developed static force presses, in which the earth is compressed in a mould between two converging plates. This process was used to make bricks for firing with varying degrees of success.

It was only in 1952 that the first press specially designed to produce compressed earth blocks came onto the market: the CINVA-RAM press designed by Raul Ramirez, an engineer working at the CINVA Centre in Bogota, Columbia. This coincided with a major breakthrough in compressed earth block technology, with large-scale construction programmes for compressed earth block buildings springing up everywhere, particularly in Latin America and in Africa: Sudan, Congo, Zaire, Guinea, Madagascar, Burundi, Rwanda, Zimbabwe, etc. Alongside this activity came many scientific research and technological development programmes aiming to master large scale production. After a lull in the 60s, there was a resurgence of interest in the mid-70s. The 80s saw the technology attracting the attention of building industry professionals the world over, and they developed a whole new range of production machines including high speed industrial production chains. Simultaneously many building companies adopted earth building technology, the applications of which began to spread from private to public markets.

Since the 90s, CEB manufacturing technology has been widely disseminated amongst the small and medium-sized enterprises of ACP countries. Architectural and technical practices in these regions are now taking an interest in CEBs when designing building projects, and both public and private real estate companies have recently begun to incorporate CEBs into their housing programmes, demonstrating that this material is now accepted by building sector professionals.

The CDE is keen to see this industry grow because it exploits locally available natural resources such as earth and it creates jobs. The technology is also easy to learn and the level of investment is within reach of small and medium-sized industrial enterprises. In this respect, the CDE has assisted many ACP promoters in a number of different ways:

- studies for preliminary project diagnosis;

- studies for production unit installation;

- identifying European technical partners with economically attractive equipment and interested in transfering their skills and knowledge;

- staff training for many SMEs in the context of demonstration projects;

- improving the technical and economic performances of CEB manufacturing units.

In addition to being involved in projects as such, together with CRATerre-EAG the CDE has played an active part in promoting the technology. An exhibition of some twenty panels presents the various types of block, the manufacturing technologies and a few well-known examples in Africa. This exhibition has been presented at several industrial fairs in collaboration with the European Commission.

Turning to publications, the CDE with the assistance of CRATerre-EAG has produced a guide listing equipment available in ACP and EU countries, selection criteria for manufacturing equipment and how to carry out a low-cost economic feasibility study on developing this product. 3,000 copies of this highly successful guide have already been distributed amongst SMEs, NGOs and development institutions in ACP countries.

The guide entitled "Compressed Earth Blocks: Standards" came out shortly afterwards, with a print run of 1,000 copies. This aims to overcome the relative absence of standards on CEB production and use and presents a consistent series of standards which are recognised as African Regional Standards and which should ultimately make it easier to draw up national standards. This practical document is aimed at building industry professionals and can also be used very like an instruction manual by those responsible for the standardisation of this building material in their own country.

1.2. Relevance and objectives of this guide

The present guide naturally forms part of the promotion activities for the CEB industry undertaken over the past few years, and should be seen in conjunction with the two previously mentioned guides in the CDE's "Technologies" series on Compressed Earth Blocks, i.e.:

- N° 5, Compressed Earth Blocks: Production equipment, 1994.

- N° 11, Compressed Earth Blocks: Standards, 1998.
  The standards published here were also adopted as African Regional Standards by the African Regional Organization for Standardization (ARSO), which has 24 ACP member states.

These publications have had a definite impact: by clearly identifying and setting out technical markers, they have became shared references, facilitating exchanges and greater confidence in the technology amongst all stakeholders. This shared reference is in itself clear evidence that the technology is understood. It also shows that practices and our knowledge of the technology are shared and therefore reliable.

CEB industry professionals increasingly refer to the CDE/ARSO standards. They have been adopted by several countries which had none previously and they are used as a basis for revising existing standards in countries which did have national CEB standards. These standards set the different specifications and performances which must be achieved without stating the various measuring and application procedures. The present publication therefore aims to bridge this gap by setting down:

- raw material identification and suitability test procedures,

- finished product performance test procedures.

The decision not to include test procedures in the Guide on standards (N°11) was made for a number of reasons:

- the first is that, although the latter document broke new ground in presenting a complete series of standards relating to the products and to their use, adding detailed test procedures to these would have made it a very bulky document, the content of which addressed different audiences. Given the specific nature of the subject, it therefore seemed preferable to publish test procedures separately, as they are primarily aimed at testing laboratories, and standards relating to CEB technology as a whole are not necessarily relevant to external laboratories;

- the second on the other hand relates to regional or international standardisation of materials testing procedures. There are in fact already various international materials testing standards, as well as draft standards relating to CEBs. We therefore believed at the time of writing the Guide on standards that this relative vacuum would be quickly filled when these draft CEB testing standards were approved. These hopes having failed to materialise to date, and given the very strong demand following the publication of the Guide on standards, it became apparent that there was a genuine need and that it was therefore important to respond to it as quickly as possible.

The present Guide does not therefore (at the time of publication) have the force of a standard, but it is, however, indispensable in order to apply CEB standards, since it enables one to ensure that the performances specified in these standards have indeed been achieved and conform to a given procedure.

Part of the work of the geomaterials laboratory (DGCB – URA of the CNRS n° 1652 of the ENTPE (National Engineering Institute for Public Works of Lyon) since 1983 has focused on testing for CEB technology (raw materials and products). The laboratory also plays an active role in the scientific circles specialising in this field. It was therefore vital for it to be closely involved in producing this guide, not only because of the reliability of its work but

also because of the major part its work has played in codification. This has enabled an initial consensus to be achieved, and although this does not have the force of a standard, it does nevertheless enable a document based on scientific experimentation and knowledge of current practices to be established.

The guide also has a broader objective, i.e. to facilitate the introduction of a quality approach or culture amongst the producers and users involved.
This means exchanges between the various practitioners in the production and distribution chain, e.g. between internal control and external control. There can be no exchanges, however, if the various stakeholders do not share a common reference such the one as the present publication hopes to provide.

The various tests are defined on the basis of the values which are provided in the guide on standards and the procedures can be used both by laboratories and by SME/SMIs.
This means above all that specialised SME/SMIs will thus be able to define precisely the performance of their products to the outside world, but will do so in liaison with laboratories, quality control bodies and technical centres which will be able to use uniform, comparable and recognised procedures, making it easier for them to evaluate the performance of the industry's products. Clients and contractors will be able to turn to laboratories to obtain performance evaluations and will obtain reliable answers, enabling them to provide guarantees of their building work to users.

Thus there will no longer be any cause for confusion in exchanges between internal control systems, and external controls and users, leaving the way clear for a genuine dynamic link between the various stakeholders, stimulating the qualitative progress of the industry, notably by paving the way for certification.

1.3. Technical assumptions

Quantitative and qualitative tests:

The procedures described in this guide relate only to quantitative tests (laboratory tests). Qualitative tests (field tests) are mentioned in the Guide on standards together with the references for the works which can be consulted for their procedures. By their very nature, the latter tests yielding no results in terms of values, there is less need for procedures to be harmonised.

Compressive strength of products and of walls:

The test procedures enable the performances mentioned in the CEB Guide on standards[1] to be measured. It is important to note, however, that although these performances enable products to be classified and designated, they are not obligatory for their use.
This is particularly the case for the stability of built structures, where the following was stated in the standards for CEB masonry specifications[2]: *the dry compressive strength of the CEBM wall (f_k) must be at least equal to the dry compressive stress at the foot of the wall*[3] *[..] in a dry or protected environment the CEBs must have a dry compressive strength (f_b dry) at least equal to 10 times the value of the dry characteristic compressive strength (f_k) required for the wall [...] in a wet environment [...] the CEBs should have a wet compressive strength (f_b wet) which is at least equal to 10 times the value of the dry characteristic compressive strength (f_k) required for the wall* [4].
This therefore means – for example - that for low characteristic dry compressive strengths of the wall (f_k), it would be possible to use CEBs with lower compressive strength values (f_b) than those given in the product classification tables[5].

The procedures described for testing the strength of CEBs are the first stage in the elaboration of standards carried out by the geomaterials laboratory of the ENTPE of Lyon.
The development of these product testing procedures has been closely linked to that of tests measuring the behaviour of walls, so that ultimately one will be able to obtain the strength of masonry structures from product performances.

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[1] ARS 674: ordinary CEBs, ARS 675: facing CEBs, ARS 676: ordinary earth mortars, ARS 677: facing earth mortars.

[2] ARS 678: ordinary masonry, ARS 679: facing masonry.

[3] ARS 678, § 2.5.1. and ARS 679, § 2.6.1.

[4] ARS 678, § 2.5.2. and ARS 679, § 2.6.2.

[5] ARS 674 to 677

The relationship between the compressive and the bending strength of products, whatever the testing method used, has not been included, given that the bending strength values of CEBs cannot be deduced directly from their observed and recorded behaviour as they can for other materials. Observed and recorded behaviour appropriate to CEBs is currently being developed. This will enable coefficients relating to the heterogeneity of these materials to be used, by determining these coefficients thanks to a series of laboratory tests. In more concrete terms, this means that the bending test for CEBs, whether carried out in laboratory or in the field (using block breaking equipment), is relevant as a qualitative test established on the basis of a calibration specific to given raw materials and production methods, but which can on no account be regarded as a quantitative test to determine the values set by ARS standards for CEBs.

The use of mass rather than weight:

We have chosen to take account of mass rather than of weight, since balances measure a weight but display a mass. This therefore avoids having to do a mass/weight conversion (P = m x g) for all measures and calculations.

Abrasive strength test:

The procedure described for the abrasive strength test is new, as such, it is based on experiments carried out nearly 40 years ago in Ghana and on many qualitative tests carried out by CRATerre-EAG. Clearly, however, the extent to which it can be reproduced has yet to be fully demonstrated, and this is particularly true if the shapes of the blocks vary. For this reason the notion of an "abrasion coefficient" has been introduced. We can therefore only urge the readers of this guide to carry out this test and to send us their comments so that these can be taken into account in future editions.

This comment applies in fact to all the procedures described. The guide is not exhaustive and will be revised in the light of progress in research and in establishing standards in this field.

Capillary absorption:

The procedure and the method of calculating the measure of the absorption coefficient are similar to current practice for other small masonry elements. The advantage of this analogy of procedure and of calculation is that it makes it easier to apply this test to CEBs in laboratories and to do so without needing to change apparatus and procedures. It also makes it easier to compare the characteristics of CEBs and those of other materials.

The procedure proposed measures the speed of absorption, since time is taken into account; this value if generally speaking highly representative of what might be observed on a masonry structure exposed to a violent storm in real life conditions.

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GENERAL CONSIDERATIONS

1. Object and field of application

The object of the present chapter is to provide definition references and if necessary to define the main terms applicable to test procedures relating to compressed earth block (CEB) technology as defined by the standard ARS 670: 1996 – Compressed earth blocks – Standard for Terminology.

2. Definitions

Absorb: to allow a fluid, or particles to penetrate and to be retained within a substance.

Adsorb: to retain by a solid at its surface molecules of a gas or of a substance in solution or in suspension.

Aqueous solution: a soil sample placed in suspension in demineralised water.

Calculator graph: graphic representation enabling one to read values in relation to functions.

Capillarity: surface tension between soil particles and water as a result of which water is drawn up in the soil.

Mineralogical composition: describes the constitution of inorganic substances making up the material, notably clays.

Consistency of a soil: describes the solidity and the cohesion of a soil.

Dispersing agent: a product used in sedimentation analysis to achieve better separation and to prevent particles from binding together again.

Equivalent diameter (of particles): in the sedimentation analysis test, the diameters and percentages of elements are calculated by simplification (Stokes' law) (e.g. by assuming that the clay particles are not platelets but are spherical in shape); since such diameters are not measured (notably by sieving) but calculated, they are known as equivalent diameters.

Fines: soil particles the diameter of which is less than 80 µm.

Fraction d/D: part of a sample defined by the material passing a Dmm sieve and retained by a dmm sieve. In other words, the d/D fraction of a soil defines those particles the diameters of which are greater than dmm and smaller than Dmm.

Homogeneous suspension: regular dispersal of particles in the liquid in question, as opposed to dispersed suspension.

Hydrometer: instrument for measuring the density of liquids.

Hygroscopic: said of a material capable of absorbing water.

Imbibition: action of absorbing a liquid.

Interstitial water: the water present in the pores of the soil which can evaporate at 105°C.

Meniscus: the curved surface of a liquid towards the sides of its container, due to capillarity.

Mesh : quadrilateral made up of four metallic wires forming the fabric of the sieve.

Molecular mass: the mass of a mole of atoms, given that a mole contains $6,023 \times 10^{23}$ atoms (Avogadro's number).

Mono-molecular layer: layer composed of a single molecule (in the Methylene blue test).

Mortar fraction: part of ■ sample defined by sieving at 0,4 mm.

Particle size measurement: determination of the respective quantity of the various particles by class of size.

Passing fraction: part of ■ sample having passed through a column of sieves or a given sieve.

Retained fraction: part of a sample retained by ■ column of sieves or by ■ given sieve.

Stabilised (soil ▬ earth): modification of the properties of ■ soil-water-air system, thanks to which in particular the properties obtained are conserved vis-à-vis the action of water.

Sieve: instrument for sieving, consisting of ■ surface with openings at regular intervals and of the same shape and size (sieve base) and a rigid frame.

Sieving: operation to separate ■ series of particles according to their size, by using one or more sieves.

Sieved fraction: see Passing fraction.

State of a soil: a soil may be in one of 3 states:
- if the soil can readily take up the shape of its container, it is in a liquid state.
- if it can be moulded and will retain the shape it is given, regardless of that of its container, it is in a plastic state.
- other than in these 2 states, the soil is in ■ dry state.

Specific surface area: the surface area provided by 1 gram of soil and which is accessible to water.

3. Symbols and units

3.1 Symbols and basic units of measurement :
Table 1 — Symbols and units for basic measurements

Symbol	English	French	Units		Unit used in the building sector
L	Length	Longueur	metre (US: meter)	m	m, cm, mm
F	Force	Force	newton	N	MN, kN
s	Pressure, Stress	Pression, Contrainte	pascal	Pa	$Pa = N/m^2$; $kPa = kN/m^2$; $MPa = MN/m^2 = N/mm^2$
m	Mass	Masse	kilogram, kilogramme	kg	t, kg, g
t	Temperature	Température	degrees Celsius	°C	°C
T	Time	Temps	second	s	h, min, s
S	Area	Surface	Square metre (US: meter)	m^2	m^2, cm^2, mm^2

Table 2 — Physical constants

Symbol	English	French	Units
N	Avogadro's number = $6{,}023 \cdot 10^{23}$	nombre d'Avogadro = $6{,}023 \cdot 10^{23}$	1/mol
ρ_w	Density of water = 1000	Masse volumique de l'eau = 1000	kg/m^3

3.2 General notations: Table 3 — Symbols and units for general notations

Symbol	English	French	Formula	Units
m_h	Wet mass	Masse humide		g, kg
m_d	Dry mass	Masse sec		g, kg
m_w	Mass of water	Masse d'eau		g, kg
m_t	Evaporating dish or tare mass	Masse coupelle ou tare		g, kg
m_{td}	Evaporating dish or tare mass + dry sample mass	Masse coupelle ou tare + masse échantillon sec		g, kg
m_{th}	Evaporating dish or tare mass + wet sample mass	Masse coupelle ou tare + masse échantillon humide		g, kg
m_{tc}	Evaporating dish or tare mass + heated sample mass	Masse coupelle ou tare + masse échantillon chauffé		g, kg
V	Volume of sample	Volume de l'échantillon		cm^3, m^3
W	Water content	Teneur en eau	$W = \dfrac{m_w \times 100}{m_d}$	% mass
W_{opt}	Optimum water content	Teneur en eau optimale		% mass
ρ_d	Dry density	Masse volumique sèche	$\rho_d = \dfrac{m_h}{V \times (1+W)}$	kg/m^3
ρ_h	Apparent density	Masse volumique apparente	$\rho_h = \dfrac{m_h}{V}$	kg/m^3
ρ_s	density of solid grains	Masse volumique des grains solides	$\rho_s = 2700$ [1]	kg/m^3
m_{stab}	Mass of binder	Masse de stabilisant		g, kg
T_{stab}	Binder content	Teneur en stabilisant	$T_{stab} = \dfrac{m_{stab} \times 100}{m_d}$	% mass
m_o	Mass of organic matter	Masse de matières organiques		g, kg
T_o	Organic matter content	Teneur en matières organiques	$T_o(\%) = \dfrac{m_o \times 100}{m_d}$	% mass
D ; d	Maximum diameter of the particles	Diamètre maximal des particules		mm
0/d	Fraction of grains between 0 and d mm	Fraction granulométrique entre 0 et d mm		
W_l	Liquid limit	Limite de liquidité		% mass
W_p	Plastic limit	Limite de plasticité		% mass
I_p	Plasticity index	Indice de plasticité	$I_p = W_l - W_p$	
MB(0 / d)	Methylene blue value of the 0/d fraction of soil	Valeur de bleu de méthylène de la fraction 0/d du sol		
MBS	Methylene blue value of the entire soil	Valeur de bleu de méthylène du sol total		
V_L	Total quantity of methylene blue solution injected	quantité totale de solution de bleu de méthylène injectée		cm^3
SST (0/d)	Total specific area of 0/d fraction of soil	Surface spécifique totale de la fraction 0/d du sol		m^2/g
SSTF	Total specific area of particles smaller than 2 μm	Surface spécifique totale des particules inférieures à 2 μm		m^2/g
L [2]	Length of CEB	Longueur du BTC		mm, cm
w [2]	Width of CEB	Largeur du BTC		mm, cm
h [2]	Heigth of CEB	Hauteur du BTC		mm, cm
t_m	Thickness of mortar	Epaisseur du mortier		mm, cm
$f_b dry$	Dry compressive strength of CEB tested in homogeneous conditions	Résistance à la compression sec du BTC testée dans des conditions homogènes		MPa, N/mm^2
$f_b{}^t dry$	Dry tensile strength of CEB	Résistance à la traction sec du BTC		MPa, N/mm^2
f_b wet	Wet compressive strength of CEB	Résistance à la compression humide du BTC		MPa, N/mm^2

Symbole	Anglais	Français	Formula	Unités
f_b^t wet	Wet tensile strength of CEB	Résistance à la traction humide du BTC		MPa, N/mm^2
f_m dry	Dry compressive strength of mortar	Résistance à la compression sec du mortier		MPa, N/mm^2
f_m^t dry	Dry tensile strength of mortar	Résistance à la traction sec du mortier		MPa, N/mm^2
f_m wet	Wet compressive strength of CEB	Résistance à la compression humide du mortier		MPa, N/mm^2
f_m^t wet	Wet tensile strength of CEB	Résistance à la traction humide du mortier		MPa, N/mm^2
E_b	Young's modulus of CEB	Module de Young du BTC		N/mm^2
V_b	Poisson's ratio of CEB	Coefficient de Poisson du BTC		
E_m	Young's modulus of mortar	Module de Young du mortier		N/mm^2
V_m	Poisson's ratio of mortar	Coefficient de Poisson du mortier		
h_{ef}	Effective height of wall	Hauteur effective du mur		cm, m
t	Thickness of wall	Epaisseur du mur		cm, m
f_k	Dry characteristic compressive strength of masonry	Résistance nominale à la compression sec de la maçonnerie		MPa, N/mm^2
f_{vk}	Dry characteristic shear strength of masonry	Résistance nominale au cisaillement sec de la maçonnerie		MPa, N/mm^2
f_{vko}	Dry characteristic shear strength of masonry without precompression	Résistance nominale au cisaillement sec de la maçonnerie sans précompression		MPa, N/mm^2
C_b	Water capillary atraction Absorption coefficient	Coefficient d'absorption d'eau par capillarité		
C_a	Abrasion coefficient	Coefficient d'abrasion		cm^2/g

NOTES:
(1) the value of the density of solid particles is variable; it is therefore preferable to measure it in the laboratory; failing this, however, one should use the conventional approximate value which is 2700 kg/m^3.
(2) these are actual measured values.

Compressed Earth Blocks: testing procedures

4. References

ARS 671 : 1996 -   Compressed earth blocks – Standard for definition, classification and designation of compressed earth blocks

ARS 672 : 1996 -   Compressed earth blocks – Standard for definition, classification and designation of earth mortars

ARS 673 : 1996 -   Compressed earth blocks – Standard for definition, classification and designation of compressed earth block masonry

ARS 674 : 1996 -   Compressed earth blocks – Technical specifications for ordinary compressed earth blocks

ARS 675 : 1996 -   Compressed earth blocks – Technical specifications for facing compressed earth blocks

ARS 676 : 1996 -   Compressed earth blocks – Technical specifications for ordinary mortars

ARS 677 : 1996 -   Compressed earth blocks – Technical specifications for facing mortars

ARS 678 : 1996 -   Compressed earth blocks – Technical specifications for ordinary compressed earth block masonry

ARS 679 : 1996 -   Compressed earth blocks – Technical specifications for facing compressed earth block masonry

ARS 680 : 1996 -   Compressed earth blocks – Code of practice for the production of compressed earth blocks

ARS 681 : 1996 -   Compressed earth blocks – Code of practice for the preparation of earth mortars

ARS 682 : 1996 -   Compressed earth blocks – Code of practice for the assembly of compressed earth block masonry

ARS 683 : 1996 -   Compressed earth blocks – Standard for classification of material identification tests and mechanical tests

RAW MATERIAL
IDENTIFICATION TESTS

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Water content test

Compressed earth blocks : testing procedures

WATER CONTENT

1. General

1.1. Object of the test

The test enables the water content of a sample to be identified.
The water content (W) expressed as a % is the quotient of the mass of free water (m_w) contained in the sample by its dry mass (m_d).

$$W(\%) = \frac{m_w \times 100}{m_d}$$

1.2. Principle of the test

Water is driven off a sample of soil by oven drying. The masses of the sample and of the evaporated water are measured by weighing.

2. Apparatus

2.1. Special apparatus

- Ventilated drying oven capable of maintaining a temperature of 105°C.
- A balance readable to 600 g and accurate to 1/10 g.

2.2. Apparatus in common use

- Dishes suitable for the quantity of the sample and capable of withstanding the oven temperature.

3. Preparing the sample

The mass (m, expressed in g) of a whole or disturbed soil for which the water content is to be determined is selected in the light of the size of the particles of the coarsest grains which the soil contains (D, expressed in mm).

If the size of the grains is less than 0.4 mm, the mass of the test sample should be such that $m \geq 10\ D$.

If the size of the grains is greater than or equal to 0.4 mm, the mass of the test sample should be greater than 200g and in addition $m \geq 200\ D$. In this event, the maximum size of the coarsest elements is assessed visually.

4. TEST PROCEDURE AND CALCULATIONS

4.1. Test procedure

- Determine the quantity required for the test sample.
- Select the appropriate size dish.
- Measure the mass of the dish or tare mass (m_t expressed in g).
- Measure the mass of the dish including the sample l.e. tare mass + wet sample mass (m_{th}, expressed in g).
- Place the dish containing the sample in the ventilated oven set to 105°C for 24 hours.
- Measure the mass of the dish including the dry sample (m_{td}, expressed in g).
- Return the dish to the oven for 2 hours.

- To check drying: measure the mass of the dish; if the mass measured is the same as that previously measured, then it is indeed the dry mass; otherwise, return the dish to the oven until a constant mass is obtained; the mass will be considered constant when two successive weighings carried out at an interval of 24 h show ■ reduction in mass of < 0.1 % of the initial mass.

Note : A micro-wave oven can be used, in which case the drying time is 15 minutes (instead of 24 h) and the drying cross-check will take between 3 and 5 minutes (instead of 2 h).

4.2. Calculations

- quantity of water contained in the sample (m_w, expressed in g) :
  $$m_w = m_{th} - m_{td}$$

- mass of dry solid grains (m_d, expressed in g) :
  $$m_d = m_{td} - m_t$$

- water content:
  $$W(\%) = \frac{m_w \times 100}{m_d}$$

5. Reporting of results

See following page.

TEST RESULTS FORM: WATER CONTENT

SAMPLE:	*red clayey soil N° 4B*	ORIGIN: *XY*
OPERATOR:	*NN*	LABORATORY: *YZ*
DATE:	*21/06/00*	

Determination of the mass of the sample tested

- mass of sample tested: m
- size of the coarsest elements the soil contains

$$D = 5 \; mm$$

D < 0.4 mm ?	D ≥ 0.4 mm ?
↓	↓
$m \geq 10\,D$	$m > 200 \; g \; and = m \geq 200$
	D
⇓	⇓
m =	*m = 1000 g*

Determination of the water content

number of the evaporating dish	5
mass of the evaporating dish = m_t (g)	*152*
mass of evaporating dish + wet sample = m_{th} (g)	*1 043*
mass of evaporating dish + dry sample = m_{td} (g)	*924*
mass of water in the sample = m_w (g) = m_{th} - m_{td}	*119*
mass of solid dry grains = m_d (g) = $m_{td} - m_t$	*772*
water content = $W(\%) = \dfrac{m_w \times 100}{m_d}$	*15.4 %*

Particle size distribution analysis with preliminary sieving of fines

Particle size distribution analysis without preliminary sieving of fines

Compressed earth blocks : testing procedures

PARTICLE SIZE DISTRIBUTION: WET SIEVING

1. General

The material which passes through the mesh of a sieve is known as the "sieved" or "passing fraction".
The material which remains in the sieve is known as the "retained fraction".

1.1. Object of the test

To identify the percentage mass of the various elements of a soil, the sizes of which are greater than 0.08 mm. This test is quantitative and give no indication of the mineralogical nature of these grains.

1.2. Principle of the test

The test consists of separating - by means of a series of sieves - material into several granular classes of decreasing size. The mesh dimensions and the number of sieves are selected in the light of the nature of the sample and the degree of accuracy expected.

The masses of the various retained fractions or those of the various passing fractions are compared to the total mass of the material. The percentages thus obtained are then used either in their numerical form, or in the form of a graph (particle size distribution curve).

The test is carried out using two distinct procedures:

• wet sieving intended first of all to separate the fines (< 0.08 mm), which then enables the "coarse" elements to be easily sieved since the cohesive elements (fines) have been removed. Some of the fines can if necessary be set aside for the sedimentation test.

• a second procedure which can be carried out for purposes of cross-checking, and which requires a smaller mass of sample than for the first procedure. In this procedure, the sample is sieved starting with the largest mesh size and gradually reducing the mesh size to the smallest diameter. The advantage of this procedure is that it enables the mass of the fines to be accurately measured and then added to the mass of the coarser elements, in order to check that this does in fact equal the initial total mass. The disadvantage is that the fines need to be washed at each sieving which makes the procedure a great deal more laborious.

Note : The second procedure should therefore be used when the sample mass is low in order to reduce the risks of inaccuracy.

2. Apparatus

2.1. Special apparatus

A minimal series of 200 mm ø sieves with square meshes of the following dimensions: 20/10/5/2/1/0,4/0,2/0,1 and 0.08 mm.

2.2. Apparatus in common use

- A ventilated oven capable of maintaining a temperature of 105°C,
- a balance readable to 10 kg and accurate to 1 gram. For masses > 10 kg a degree of accuracy of ± 5 g may be permissible,
- at least 3 trays measuring 40 x 30 x 6 cm (alternatively 30 x 22 x 5 cm),
- 500 ml flexible plastic wash bottles,
- a hotplate or alternatively a micro-wave oven,
- a scoop,
- a sieve brush with nylon hairs,
- a spatula,
- a pair of insulated gloves.

3. Preparing the sample

3.1. Quartering

- Make a conical pile of the material to be divided into samples in a high-sided tray.
- Flatten the pile.
- Divide the pile into four quarters taking care not to lose any fines.
- Discard two diagonally opposite quarters.
- Make a new cone with the remaining material.
- Repeat the operation until the amount required has been obtained.
- The mass of the test sample depends on the size of the coarsest elements it contains. It is recommended that the limits set by the following formula should be respected:

$$200\,D < m < 600\,D$$

where m is the mass of the sample expressed in grams and D the maximum size expressed in millimetres of the coarsest aliments.

3.2. Preparing

The test is carried out on material at the water content at which it is found before the analysis in order to avoid it drying out, which would present certain disadvantages, i.e. loss of time due to drying before sieving, and the possibility that particles would stick together while drying.

Two representative samples of the material are obtained by quartering.

- the first of mass m_h, to carry out the particle size distribution analysis by preliminary sieving of the fines (< 0.08 mm);
- the second of mass m_{1h} to check the dry mass without preliminary sieving of the fines (see note § 1.2.);
- the two samples are weighed;
- complete desiccation of the first sample m_{1h} which is then weighed. Let m_{1d} be its dry mass;
- the dry mass (m_d) of the sample subjected to particle size distribution analysis is calculated as follows:

$$m_d = \frac{m_{1d}}{m_{1h}} \times m_h$$

4. Test procedure and calculations

4.1. Test procedure with preliminary sieving of fines

- Take the sample m_h and leave it to soak beforehand for 2 to 24 hours.
- Sieve using a 0.08 mm mesh sieve and reserve the retained fraction and if necessary part of the passing fraction (fines) for the sedimentation test.
- Take the temporary vessel containing the retained fraction, place it in ■ drying oven and dry it until a constant mass is obtained; the mass will be considered constant when two successive weighings carried out at an interval of 24 h show ■ reduction in mass of < 0.1 % of the initial mass. A micro-wave oven also can be used, as can ■ hotplate.
- Weigh the total mass of the dry retained fraction. Let R be this total mass.
- Pour the dry retained fraction into a column of sieves arranged in decreasing order from the top.
- Shake the column manually or mechanically, then remove each sieve one at a time, starting with the one with the largest opening and fitting it with a receiver and ■ lid. Shake each sieve by regularly tapping the frame against the hand. Generally speaking, ■ sieving operation can be considered to be complete when the retained fraction does not change by more than 1% after one minute of sieving.
- Weigh the fraction retained by the 20 mm sieve. Let R_1 be the mass of this retained fraction.
- Pour the passing fraction onto the sieve immediately below, i.e. in this case the 10 mm mesh sieve.

- Repeat the same operation using this finer sieve; add the retained fraction obtained to R_1 and weigh the whole. Let R_2 be the mass of the two retained fractions combined. This enables the combined mass to be measured without any risk of error.
- Carry out the same operation with all the sieves in the column to obtain the masses of the various retained fractions combined i.e. R_3, R_4, ..., R_i, ..., R_n.
- Weigh the passing fraction – if any – of the final sieve. Let T_n be its mass.
- Care must be taken not to lose any elements while handling the sample. To check this, compare the original total mass of the dry retained fraction (R) with the total mass at the end ($R_n + T_n$).

4.2. Test procedure without preliminary sieving of fines

- Place the 20 mm sieve in a tray capable of holding the passing fraction, the soaking water and the washing water.
- Take the sample m_{1h} with the soaking water and carefully pour onto the sieve.
- Care should be taken to avoid the water overflowing the sieve while the sample is being poured.
- Thoroughly wash the fraction retained on the sieve using the wash bottle and the hand or the brush; this will enable the water to wash away any fine sands and fines which might still be stuck to the elements retained by the sieve.
  The material is considered to have been adequately washed when the water beneath the sieve runs clear.
- Do a final rinse above the tray using the wash bottle.
- Retrieve the retained fraction and place it in a temporary container.
- Pour the content of the tray containing the passing fraction and the water onto the next sieve in the series placed in the second tray.
- Repeat the washing process as described above.
- Retrieve the retained fraction from the sieve and place it in the temporary container which already contains the preceding retained fraction. This enables the combined mass to be measured without any risk of error.
- Continue in the same way until the 0.1 mm or the 0.08 mm sieve.
- In order to avoid damaging the mesh of the fine sieves, rather than continuing to stir by hand, using the brush is recommended.
- Stop at the 0.1 mm sieve if the intention is to retrieve the passing fraction in order to carry out the sedimentation test. If on the other hand a separate sample is prepared for sedimentation analysis, it is useful to carry on as far as the 0.08 mm sieve so that the results of the sieving and of the sedimentation tests can be compared; it is possible to carry out the sedimentation analysis using the fraction passing the 0.08 mm sieve, but it is not possible to then compare the results with the particle size analysis results.

4.3. Calculations

- After sieving, the masses of the various retained fractions combined R_i, are compared with the total calculated mass of the sample for dry testing m_s and the percentages of the combined retained fractions thus obtained, $\left(\dfrac{R_i}{m_d} \times 100 \right)$ entered onto the test sheet. The percentages of the corresponding passing fractions are equal to $100 - \left(\dfrac{R_i}{m_d} \times 100 \right)$.
- Check that there was no loss of material while the test was being carried out
  $m_d = R_n + T_n$

5. Reporting of results

Calculation form and Graph (see following pages.)

6. References

- NFP 18-560 of October 1978, "*Analyse granulométrique par tamisage*",
- NF X 11-507, "*Analyses granulométriques - tamisage de contrôle*",
- R. PELTIER, "*Manuel de laboratoire routier*", Dunod, Paris, 1969.

TEST RESULTS FORM : PARTICLE SIZE DISTRIBUTION ANALYSIS

SAMPLE:	*red clayey sand N° 4B*	ORIGIN: *XY*
OPERATOR:	*NN*	LABORATORY: *YZ*
DATE :	*21/06/00*	

LAST SIEVE SELECTED: | 0.1 mm | or | 0.08 mm X |

MEASUREMENT OF MASSES AND WATER CONTENT

First sample for preliminary sieving of fines

WET MASS OF THE SAMPLE: m_h (g)	*750*
DRY MASS OF THE SAMPLE: - either dried then m_d (g) - or based on the measurement of the water content of the 2nd sample $m_d = \dfrac{m_{1d}}{m_{1h}} \times m_h$	*650*

Second sample without preliminary sieving of fines

WET MASS OF THE SAMPLE: m_{1h} (g)	
DRY MASS OF THE SAMPLE: m_{1d} (g)	*500*

Check: $200D < m_d < 600 D$?   YES   ■
NO   ❏

SIEVING OF THE SAMPLES

TOTAL DRY MASS OF RETAINED FRACTION: R (g)	*349.2*

SIEVE MESH IN MM	MASS OF COMBINED RETAINED FRACTIONS (R_i) in grams	% COMBINED RETAINED FRACTIONS $\left(\dfrac{R_i}{m_d} \times 100\right)$	% COMBINED PASSING FRACTIONS $\left(100 - \left(\dfrac{R_i}{m_d} \times 100\right)\right)$
20	*0*	*0*	*100*
10	*0*	*0*	*100*
5	*0*	*0*	*100*
2	*0*	*0*	*100*
1	*36.5*	*7.3*	*92.7*
0.4	*239.4*	*47.88*	*52.12*
0.2	*312.2*	*62.44*	*37.56*
0.1	*336.7*	*67.6*	*32.4*
0.08	*347.3*	*69.46*	*30.54*
FRACTION PASSING LAST SIEVE (T_n) (g)			*150.8*
CUMULATED RETAINED FRACTION OF LAST SIEVE (R_n)			*347.3*
TOTAL MASS AFTER SIEVING: $R_n + T_n$			*498.1*
EVALUATION OF LOSSES: $100 \times \dfrac{m_d - (R_n + T_n)}{m_d}$ = *0.38* % < 2 % ? YES ■ NO ❏			

NOTE : The same table will be used both for wet sieving of the first sample after preliminary sieving of fines at 0.08 mm and for wet sieving of the second sample without preliminary sieving at 0.08 mm.

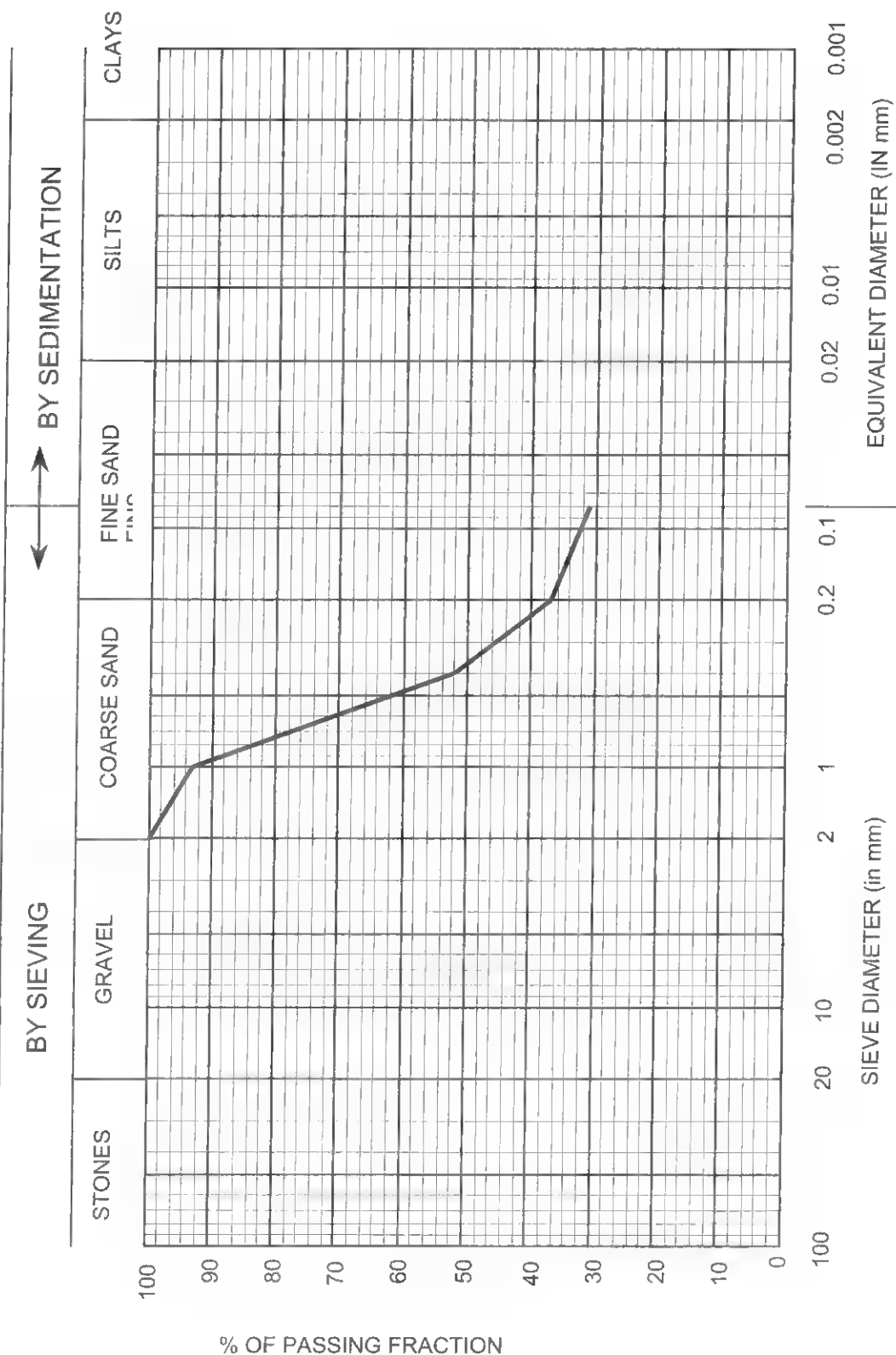## TEST RESULTS FORM : PARTICLE SIZE DISTRIBUTION ANALYSIS

SAMPLE:	*red clayey sand N° 4B*	ORIGIN: XY
OPERATOR:	*NN*	LABORATORY: YZ
DATE :	*21/06/00*	

PARTICLE SIZE DISTRIBUTION ANALYSIS

BY SEDIMENTATION

BY SIEVING

CLAYS — SILTS — FINE SAND — COARSE SAND — GRAVEL — STONES

EQUIVALENT DIAMETER (IN mm)

SIEVE DIAMETER (in mm)

% OF PASSING FRACTION

Sedimentation test

Compressed earth blocks : testing procedures

PARTICLE SIZE DISTRIBUTION: SEDIMENTATION TEST

1. General

1.1. Object of the test

Sedimentation analysis is a test which complements particle size distribution analysis by sieving. It is applied to the fine elements of less than 0.1 mm for which it is not possible to use sieves.

1.2. Principle of the test

Grains of soil of differing diameters, placed in homogeneous suspension in a standing liquid, sediment, or "fall", at differing speeds according to their diameters. In the course of this sedimentation, the density of the initially homogenous mixture will increase from the top to the bottom as time passes. By measuring times and densities and by using Stokes' law, we can obtain ■ spread of the diameters of the grains of soil which are assumed to be spherical (although they are not generally so).

Stokes' law calculates the speed of fall of the spherical grain of soil of equivalent diameter in a certain liquid.
This speed depends on the specific gravity of the grain, and on the viscosity of the liquid, which in turn depends on the temperature and on gravity acceleration.

The results are read using a hydrometer. Correction factors will therefore need to be introduced to allow for the hydrometer, the composition of the liquid, the temperature and if appropriate the density of the grains.
An important starting point of the principle of the test consists in putting the sample in homogenous suspension. In order to be sure that all the fines are broken down, the sample will be placed in a liquid containing ■ dispersal agent.

2. Apparatus and products

2.1. Special apparatus

- A torpedo-shaped hydrometer (Bouyoucos or similar) graduated 0.995 to 1.030 g/cm^3 with graduations every 0.0005 g/cm^3. (Fig. 1)
- 2 litre measuring cylinders: inner diameter 85 mm, height of graduations 450 mm or 1 litre cylinders: inner diameter 60 mm.
  Care: The sample must be prepared differently according to whether 1 or 2 l cylinders are used; the particular way to prepare it for 1 l is therefore specified in § 3.2.
- A mechanical stirrer, the speed of rotation of which can be adjusted from 0 to 10,000 r.p.m. The stirrer must be of the "plunger" type, i.e. the supporting spindle of the rotating palette is introduced into the beaker containing the solution: the beaker should not have smooth cylindrical sides. It could be for example of the kind shown in Figure 3.
- A manual stirrer to ensure that the suspension is homogeneous before the test. (Fig. 2).

2.2. Products

- A dispersing agent: sodium hexametaphosphate.
- De-mineralised wateror distilled water.

2.3. Apparatus in common use

- A thermometer readable to 1/10 degree, range approximately +10°C to +35°C.
- A stop watch displaying seconds.
- A balance readable to 200 g and accurate to 1/100 gram.
- A 0.1 mm square mesh sieve.
  (If using ■ 0.08 mm sieve, see Note § 3.2.)
- A mortar approximately 20 cm in diameter with a rubber-headed pestle.

- Ventilated drying oven capable of maintaining a temperature of 105°C.
- Spatulas and spoons.
- Two trays measuring 40 x 30 x 6 cm (alternatively 30 x 22 x 5 cm).
- A 1 litre bottle and stopper for keeping the dispersing agent.

Fig. 1. R3 Hydrometer. Scale 1/2, dimensions in mm

*Stirrer for 1 l.
measuring cylinder

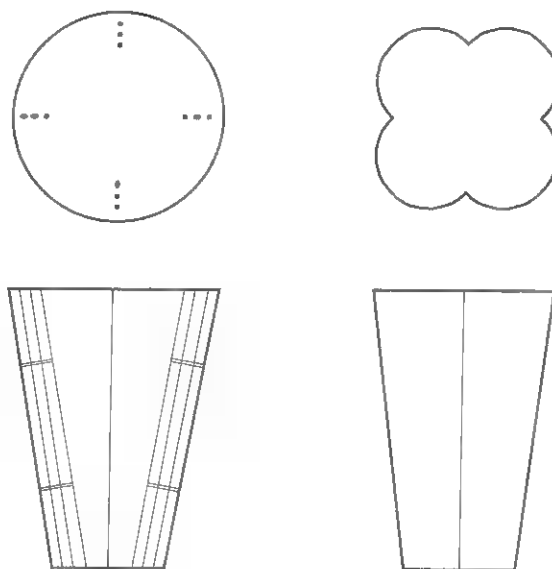Fig. 2. Manual stirrer

Compressed Earth Blocks: testing procedures

Fig. 3. Two types of beaker for use with a mechanical stirrer

3. Preparing the sample

3.1. Preparing the dispersing agent (solution of sodium hexametaphosphate)

- Place 50 g of sodium hexametaphosphate and 0.5 litres of distilled water in a glass recipient.
- Heat, stirring until the powder has dissolved completely. Avoid heating over 50°C.
- When the powder has dissolved completely, top up using distilled water to 1 litre.
- Keep the dispersing agent in ■ sealed bottle labelled with the date of manufacture.
- Do not keep the solution for more than one month.

3.2. Preparing the sample

- The fraction under 0.1 mm, retrieved after wet sieving of the soil sample, should be oven dried at 105°C until it is completely dry.

    NOTE: the test is carried out from ø < 0.1 so that the results can be compared with those of particle size distribution analysis by sieving which is carried out from D up to 0.08 mm.

    The sedimentation test can if necessary be carried out using the fraction of less than 0.08 mm, but in this event it will not be possible to compare the accuracy of the values between 0.1 and 0.08 mm.

- Once it is completely dry, the material should be broken down using a laboratory pestle and mortar, and then mixed to a homogeneous state.
- The quantity necessary to carry out the sedimentation test is then removed, i.e. 80 g of material passing 0.1 mm for a 2 litre cylinder or 40 g of material passing 0.1 mm for a 1 litre cylinder.
- The sample prepared in this way must be completely immersed for 12 to 15 hours in a vessel containing 300 cm^3 of distilled water and 60 cm^3 of dispersing agent for a 2 litre cylinder or containing 150 cm^3 of distilled water and 30 cm^3 of dispersing agent for a 1 litre cylinder.
- The suspension is then mechanically stirred, the object being to adequately separate the grains. Stirring should take place for 3 minutes at 10,000 – 12,000 r.p.m. If a mechanical, "plunger" type stirrer is not available, a domestic "food mixer" type of stirrer can be used. If so, the duration of the preliminary soaking stage should be increased, and consequently so should the stirring time.
- Pour the dispersed suspension into the 2 or 1 litre cylinder and thoroughly rinse the vessel and the stirrer.
- Using distilled water, top up to exactly 2 litres for the 2 litre cylinder and to exactly 1 litre for the 1 litre cylinder.

4. Test procedure and calculations

4.1. Test procedure

Before carrying out the test, check that the stem of the hydrometer is perfectly clean, which is very important for the meniscus to form completely. Once the test is in progress, never pick up the hydrometer other than by the upper tip of the stem.

Before inserting the hydrometer, shake the suspension well to obtain a uniform concentration from top to bottom of the cylinder. Withdraw the stirrer and simultaneously start off the stop watch, then slowly insert the hydrometer. Take readings at the top of the meniscus (fig. 4). Note the number R, i.e. the number of divisions from the 1,000 graduation onwards adding the + sign for readings above 1,000. For example 1,0185 is recorded as 18.5.
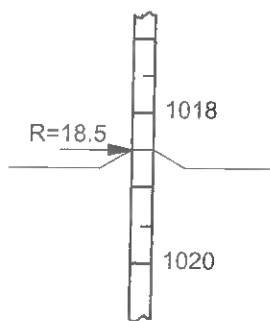

R=18.5 1018

1020

Fig. 4

Readings are taken at: 30 seconds, 1, 2, 5, 10, 20, 40, 80, 240, minutes (and possibly 1,440 minutes, i.e. after 24 hours), all these times being counted from the start of the test. The 3 readings at 30 seconds, 1 and 2 minutes are made without withdrawing the hydrometer from the suspension. Only after the 2 minute readings is the temperature of the suspension measured to the nearest 1/10 degree. For the other readings, insert the hydrometer 15 to 20 seconds before taking the reading. Note the temperature after each reading.

4.2. Calculations

- Starting from the R readings, determine the corrected readings - R_1 – taking account of :
    - the temperature (C_t),
    - the meniscus (C_m),
- the dispersing agent (C_d),
- if necessary, the specific gravity of the particles, failing which this is assumed to be 2.65 g/ m^3.

- $R_1 = R + C$ given $C = \pm C_t + C_m + C_d$

- This requires using the calibration scale established for each hydrometer, giving the correction to be made according to the temperature, the meniscus and dispersing agent (see calibrating the hydrometer in annex). Alternatively, compare results with those from a hydrometer placed in a control cylinder (see below).

- The percentage, p, of the grains for the various equivalent diameters is then calculated using the formula:

$$p(\%) = \frac{V}{m} \times \frac{\rho_s}{\rho_s - 1} \times \frac{R_1}{10} \quad \text{where:}$$

V = volume of the suspension (2,000 cm^3 or 1,000 cm^3 for the 1 l cylinder.)
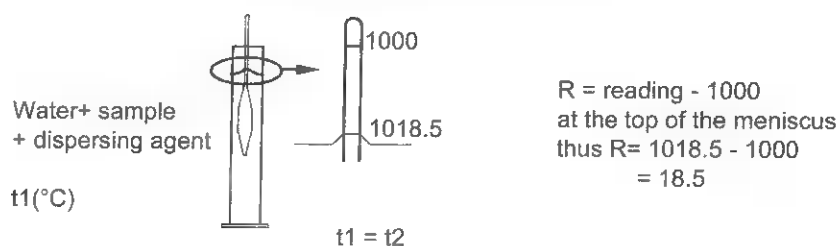m = mass of the soil sample (80 g or 40 g for the 1l cylinder.)

ρ_s = density of soil grains(2.65 g/cm^3)

R_1 = corrected reading (density of the suspension at time t.) in mg/cm^3.

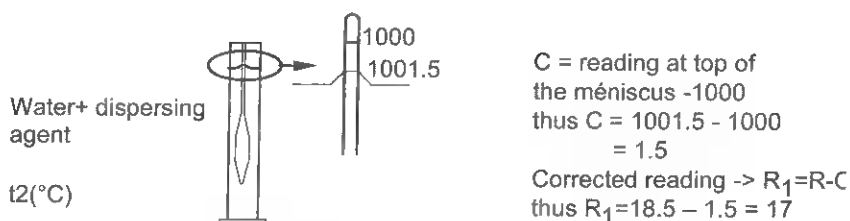After simplification one obtains: $\quad\quad\quad p = 4R_1$

- The percentage of the grains is then determined in relation to the whole of the material. The results obtained are then recorded on ■ graph in order to draw the particle size distribution curve of the soil.
- In principle, one should also calculate the equivalent diameter of the particles which corresponds to the time at which the reading is taken, i.e. to the sedimentation time of those particles at the time of the reading. The procedure does not include calculating the equivalent diameters. This is possible to the extent that laboratories are applying this procedure using hydrometers which are more or less identical to the one specified above. If the bulb diameters were not identical it would in fact be necessary to calculate equivalent diameters, particularly for the first readings.
- A simple method for obtaining the corrected readings (R_1) directly from the initial readings (R), without having recourse to the calibration described in annex consists in carrying out the test as follows:

    Prepare a second 2 litre (or 1 litre) control cylinder identical to that of the sample, containing demineralised water and the same quantity of dispersing agent as for the sample. Check that this cylinder is at the same temperature as that containing the sample and keep ■ hydrometer of the same kind permanently inserted in it.

CYLINDER CONTAINING THE SAMPLE

Water+ sample
+ dispersing agent

t1(°C)

1000

1018.5

t1 = t2

R = reading - 1000
at the top of the meniscus
thus R= 1018.5 - 1000
= 18.5

CONTROL CYLINDER

Water+ dispersing agent

t2(°C)

1000

1001.5

C = reading at top of the méniscus -1000
thus C = 1001.5 - 1000
= 1.5
Corrected reading -> R_1=R-C
thus R_1=18.5 – 1.5 = 17

- Instead of taking a single reading (R), for each set time one therefore takes a second reading (C) allowing one to calculate $R_1 = R + C$.

5. Reporting of results

Calculation form and Graph (See following pages.)

6. References

- Central bridges and highways laboratory, *"Méthodes d'essais L.C.P.C. N° 18 ; Analyse granulométrique par sédimentométrie"*, Paris, France, February 1987.
- ASTM, "Annual Book of ASTM Standards 1985. Volume 04.08 : Soil & Rock ; Building Stones", Philadelphia, Pennsylvania, ASTM 1985.

TEST RESULTS FORM : SEDIMENTATION TEST

SAMPLE:	*red clayey sand N° 4B*	ORIGIN: XY
OPERATOR:	*NN*	LABORATORY: YZ
DATE :	*21/06/00*	

MAXIMUM PARTICLE SIZE =

$D = 0.08\ mm$

SAMPLE MASS =

$m = 40\ g$

MEASURING CYLINDER USED   1 litre ■   2 litres ❏

DISPERSING AGENT = *50 g sodium hexametaphosphate per 1 l of dispersing agent*

METHOD FOR DETERMINING THE CORRECTION FACTORS
- CALIBRATION   ❏
- CONTROL CYLINDER   ■

CUMULATED FRACTION OF TOTAL SAMPLE RETAINED ON 0.1 mm or 0.08 mm SIEVE (see D)   R = 69.5 %

PASSING FRACTION OF TOTAL SAMPLE ON 0.1 mm or 0.08 mm SIEVE (see D)   T = 30.5 %

START TIME OF FINAL MIX: *9 h 20*

START TIME OF SEDIMENTATION: *9 h 40*

TIME	Equivalent diameter in µm	TIME min	TEMP. °C	R (readings)	C (corrected readings)	R_1 (R + C)	$p = 4R_1$ (1)	T x p (2)
9h 40'30	70	0.5	22	21.3	1.3	22.6	90.4	27.6
9 h 41	50	1	22	20.7	1.3	22	88	26.8
9 h 42	35	2	22	20.2	1.3	21.5	86	26.2
0945	25	5	22	18	1.2	19.2	76.8	23.4
0950	18	10	21.9	16.4	1.1	17.5	70	21.3
1000	12	20	21.9	15.6	1.1	16.7	66	20.1
1020	9	40	21.8	15.1	1	16.1	63.6	19.4
1100	6	80	21.6	14.5	1	15.5	61.2	18.7
1340	3.5	240	21.5	14	1	15	60	18.3
0940	1.5	1440	21	13	1	14	56	17.1

(1) % of the passing fraction of sample particles smaller than 0.1 or than 0.08 mm
(2) % of the passing fraction of total sample particles

SAMPLE:	*red clayey sand N° 4B*	ORIGIN: *XY*
OPERATOR:	*NN*	LABORATORY: *YZ*
DATE :	*21/06/00*	

PARTICLE SIZE DISTRIBUTION ANALYSIS

Consistency limits

Compressed earth blocks : testing procedures
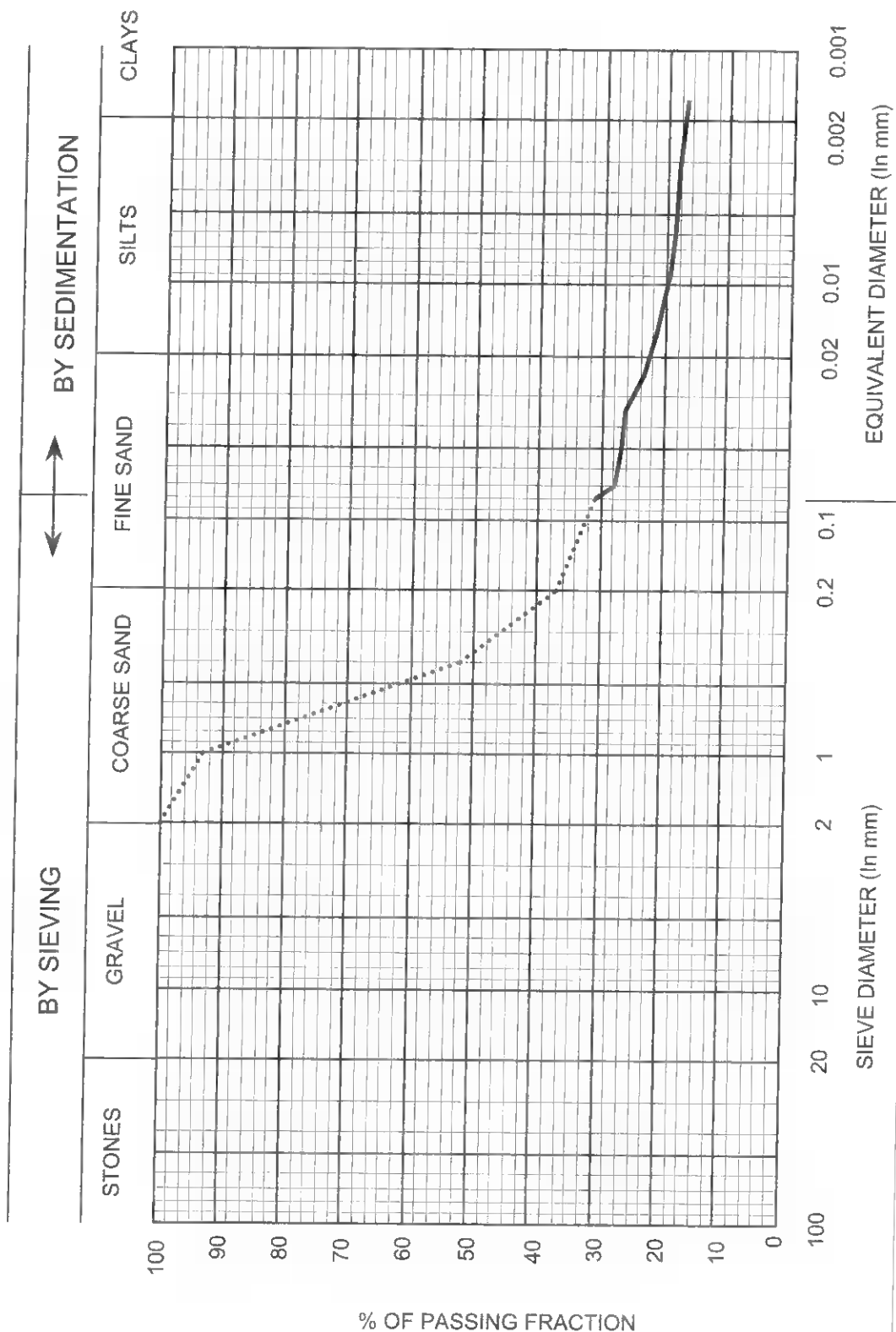
CONSISTENCY LIMITS

1. General

1.1. Object of the test

The consistency of ■ soil can vary widely with:

- The quantity of interstitial water contained in its pores;
- the thickness of the layers of adsorbed water coating its grains.

The Atterberg limits are conventional physical constants marking the thresholds between:

- The passage of a soil from a liquid state to a plastic state (liquid limit: W_l),
- the passage of ■ soil from the a plastic state to a solid state (plastic limit: W_p).

These limits indicate the water content of ■ soil at the state of transition in question, expressed as a percentage of the mass of the dry material.

The difference $Ip = W_l - W_p$, which defines the range of the plastic zone, is particularly important and is called the plasticity index.

1.2. Principle of the test

The test is carried out in two phases:

The liquid limit is water content at which the two halves of ■ cake of soil, placed in a cup and divided into two parts by a groove, come into contact along a fixed length as a result of ■ fixed number of blows (25) delivered to the cup. This is done using the Casagrande apparatus.
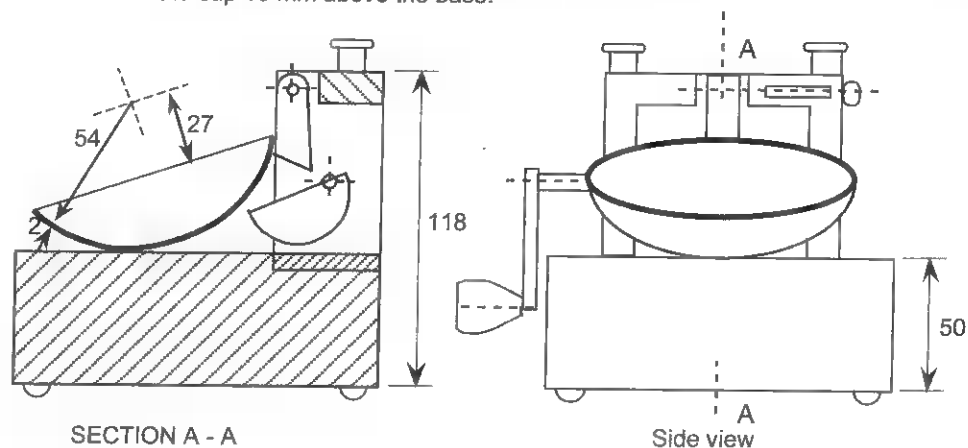
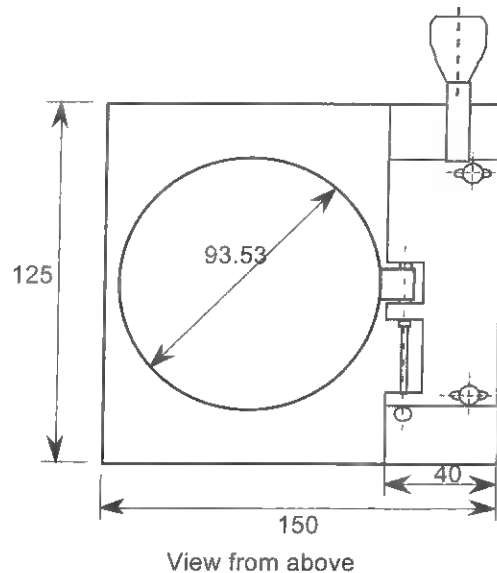The plastic limit is the water content at which it is still possible to form 3 mm diameter rolls without cracking.

2. Apparatus

2.1. Special apparatus

CASAGRANDE APPARATUS
- a base mounted on four rubber feet,
- a metal support holding the cup and the handle which turns the crank which lifts the cup 10 mm above the base.
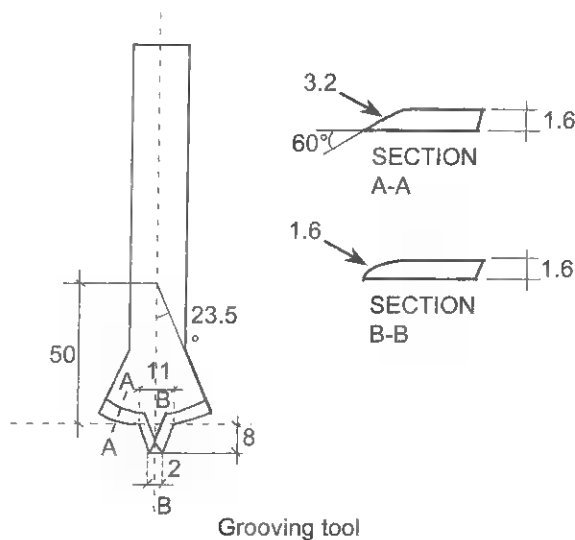

SECTION A - A   Side view

View from above

The apparatus includes two kinds of cup made of chrome-plated brass:
- a smooth cup,
- ▪ roughened cup.

Before each test, a height gauge is used to check the height of fall of the cup which should be 10 mm.

GROOVING TOOL

The grooving tool should make a 2 mm wide groove along the bottom of the cup.

Grooving tool

ACCESSORIES

- A 10 mm height gauge to adjust the height of fall of the cup,
- a glass, marble or plexiglass slab measuring approximately 25 x 25 x 0.5 cm to roll the soil into threads.

2.2. Apparatus in common ▬

- Spatulas, trowels and a marble slab for mixing the soil,
- 500 ml flexible plastic wash bottles,
- tared evaporating dishes and containers with airtight lids,
- a balance readable to 600 g and accurate to 1/10 gram.
- ventilated drying oven capable of maintaining ▪ temperature of 105°C.
- a sieve with a 0,40 mm square mesh,
- a tray measuring 40 x 30 x 6 cm (alternatively 30 x 22 x 5 cm).
- a hair dryer.

Compressed Earth Blocks: testing procedures

3. Preparing the sample

The Atterberg limits test is carried out on the fine fraction of the material, i.e. that passing the 0.40 mm sieve. The sample material is quartered when not oven dried, and a sufficient quantity being sieved to give a fine sample of 150 à 200 g.

Prior to sieving, the material must be soaked for at least 12 hours. This should be done directly in the sieve placed in a larger tray.

A wet sieving procedure should be used, stirring the material on the mesh surface using a soft brush. The retained fraction should be perfectly clean.

Once the washing water has been decanted, carefully siphon more away to avoid removing particles of less than 0.40 mm, and then evaporate the excess water at a temperature of not more than 60°C.

The particles of less than 0,40 on which the Atterberg limits test are to be carried out are then removed preferably in a doughy state.

Leave to rest approximately 12 hours after mixing with ■ spatula until an almost liquid paste is obtained.

4. Test procedure and calculations

4.1. Liquid limit (W$_l$)

Procedure

Take approximately 100 grams of the prepared sample.
Approximately 70 g of paste is spread in several layers in the cup using the spatula, forming a cake which is more or less symmetrical in relation to the symmetry of the plan of the cup[*].
In the middle of the cup, the material should be in the order of 15 to 20 mm thick.
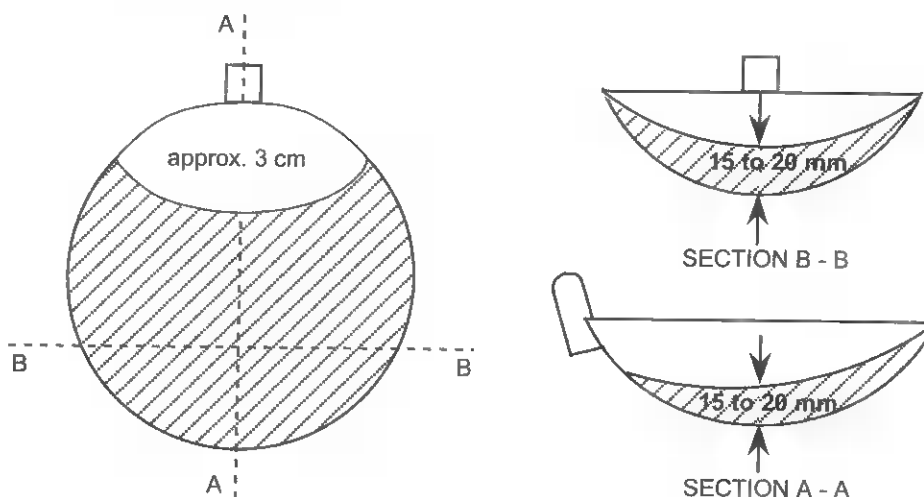
Using the grooving tool held perpendicular to the surface of the cup and with the chamfered edge facing the front of the apparatus, the paste is divided in two.

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[*] The roughened cup is used for sandy soils.

SECTION B - B
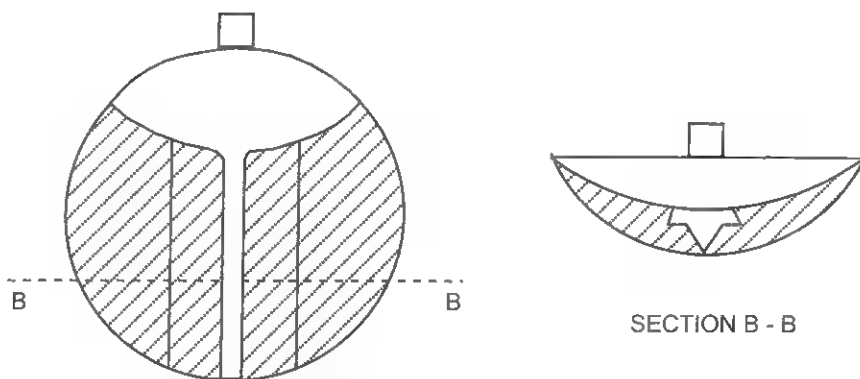
- The cup fixed to the apparatus is then subjected to ■ series of regular blows – two blows per second – using the handle to turn the crank.
- The number of blows required for the edges of the groove to come into contact along ■ length of 1 cm judged by eye is recorded. The number of blows for closure should be in the range 15 to 35. Some material is removed from each side of the edges of the groove, close to where they have come into contact. The material removed is placed in tared containers which are immediately weighed and then placed in the drying oven until complete desiccation.

The operator will carry out a control check by carrying out a second test at ■ lower water content. The number of blows should increase by at least 5 units by comparison with the first test.

1 cm

SECTION B - B
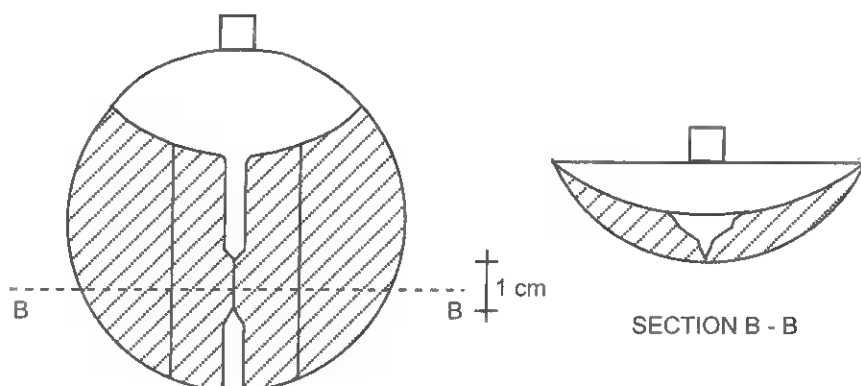
- To obtain a lower water content for the second test, the soil must be dried, while being mixed, for a little longer.

Calculations

By definition: the liquid limit is the water content of the material which corresponds to a closure along ■ distance of 1 cm of the edges of the groove after 25 blows. As it is difficult to obtain this closure at 25 blows, there is a formula, enabling one to find W_l from the water content (W) provided that the number of blows (N) is within the range 15 et 35.

The formula is written as follows: $W_l = W \times \left(\dfrac{N}{25} \right)^{0.121}$. This has been converted into a calculator graph which avoids the need to do the calculation.

Having completed both tests, the results are then recorded on the results form and the liquid limit is then calculated or found using the calculator graph.

The two liquid limits thus obtained should not differ by more than 2.5 % in either direction. If this condition is not met, a third test should be carried out.

The liquid limit is the average of the three (or four) values obtained.

Compressed Earth Blocks: testing procedures

4.2. Plastic limit (W_p)

Procedure

The plastic limit being measured after the liquid limit, the sample is often too wet and has to be dried out by stirring it, by spreading it out on ■ marble slab or by using a hair drier, stirring continuously.

A ball of soil is moulded using this paste. The ball is rolled between the palm of the hand and the slab applying gentle pressure in order to form ■ thread which is gradually reduced in diameter to 3 mm (a rod can be used to gauge this).

Once it is 3 mm in diameter, the thread should be 10 à 15 cm long and should not be hollow.

The plastic limit is reached when the thread cracks on being slightly lifted up at the middle using the rod.

If the material contains too much water, a new ball is made and kneaded to dry it and the operation is repeated until the plastic limit is reached.

The thread is then placed in a tared container which is immediately weighed, and then this is placed in the oven until complete desiccation.

A second test is carried out on another ball made from the same material.

Calculations

- By definition: the plastic limit is the water content at which the 3 mm thread, when lifted at the middle, cracks
  On completing both tests, the results are recorded on the calculation form allowing the water contents to be calculated.
- The two values obtained should not differ from one another by more than 2% in either direction. If they differ more widely, ■ third test shall be carried out.
- The plastic limit is the average of the two (or three) results obtained.

5. Reporting of results

Calculation sheet and graph (see following pages.)

6. References

- LCPC, "*Modes opératoires du Laboratoire Central des Ponts et Chaussées ; Limites d'Atterberg ; liquid limit ; plastic limit ; mode opératoire 6-4*", Dunod, Paris, France, 1970.

- Draft French standard 94-051.

TEST RESULTS FORM : LIQUID LIMIT

SAMPLE:	*red clayey sand N° 4B*	ORIGIN: *XY*
OPERATOR:	*NN*	LABORATORY: *YZ*
DATE :	*21/06/00*	

	1st test (Wl$_1$)	2nd test (Wl$_2$)	3rd test (Wl$_3$)
number of blows (N) 15<N<35	23	17	33
number of tare	1	2	3
total wet mass = m_{th}	39	36,5	38,5
total dry mass = m_{td}	34,74	32,77	35,04
tare mass = m_t	21,59	21,69	23,9
water mass = $m_{th} - m_{td} = m_w$	4,26	3,73	3,46
mass of dry soil = $m_d = m_{td} - m_t$	13,15	11,08	11,14
water content in % $\dfrac{m_w \times 100}{m_d} = W$	32,40 %	33,66 %	31,06
$W_l = W \times \left(\dfrac{N}{25}\right)^{0.121}$ calculate or read off calculator	32,07	32,13	32,12
Average LIQUID LIMIT $W_l = \dfrac{W_{l1} + W_{l2} + W_{l3}}{3} =$	32.1 %		

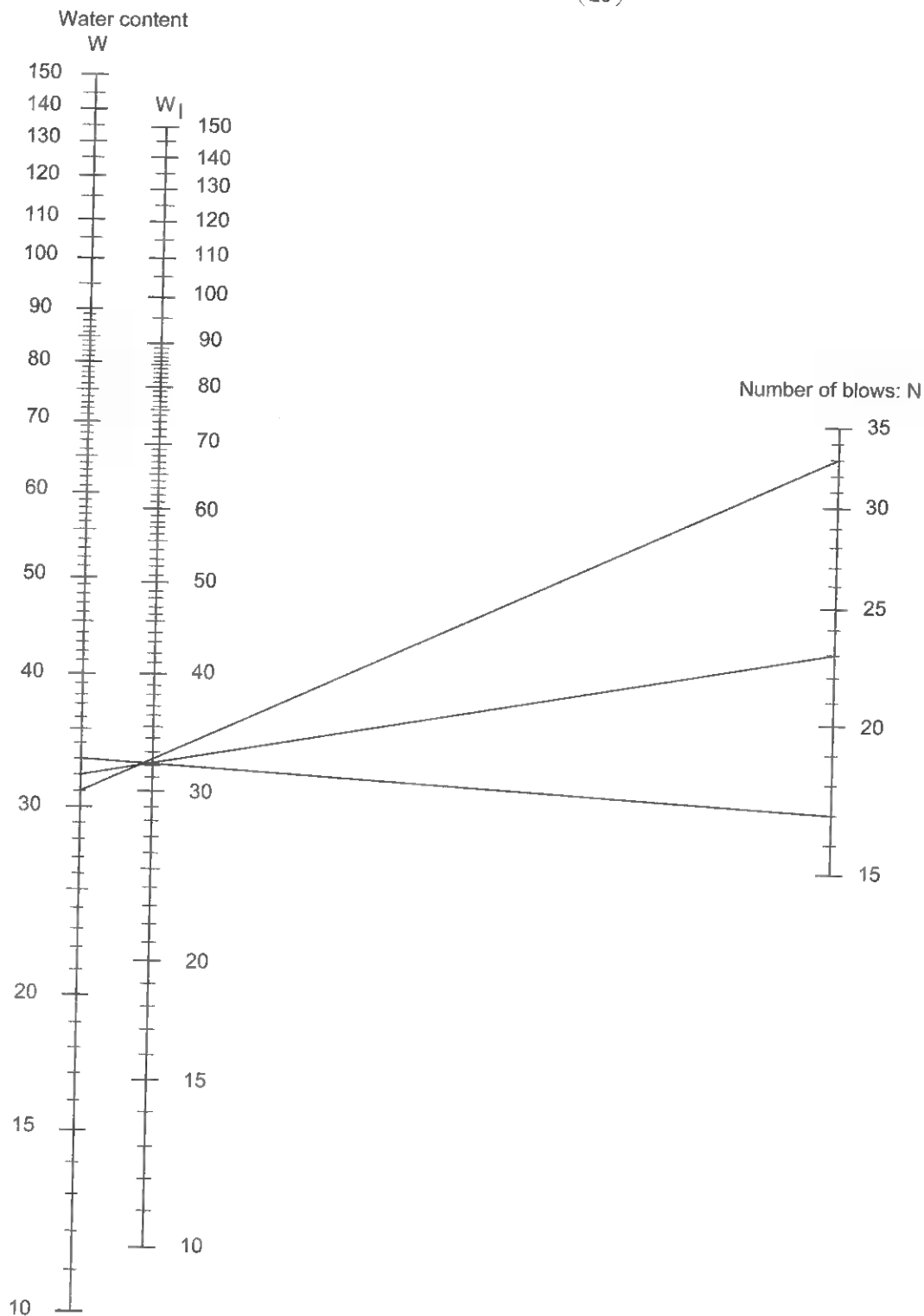| SAMPLE: | *red clayey sand N° 4B* | ORIGIN: *XY* |
| OPERATOR: | *NN* | LABORATORY: *YZ* |
| DATE : | *21/06/00* | |

CALCULATOR GRAPH FOR OBTAINING THE LIQUID LIMIT

$$W_l = W \times \left(\frac{N}{25}\right)^{0.121}$$

Water content
W

W_l

Number of blows: N

TEST RESULTS FORM : PLASTIC LIMIT

SAMPLE:	*red clayey sand N° 4B*	ORIGIN: *XY*
OPERATOR:	*NN*	LABORATORY: *YZ*
DATE :	*21/06/00*	

PLASTIC LIMIT

	1st test (W_{p1})	2nd test (W_{p2})	3rd test (W_{p3})
number of the tare	*1*	*2*	*3*
total wet mass = m_{th}	*37.5*	*38.4*	*38.5*
total dry mass = m_{td}	*34.82*	*35.94*	*35.62*
mass of the tare = m_t	*21.69*	*24*	*21.77*
mass of the water = $m_{th} - m_{td} = m_w$	*2.68*	*2.46*	*2.88*
mass of the dry soil = $m_{td} - m_t = m_d$	*13.13*	*11.94*	*13.85*
water content in % $W = \dfrac{m_w \times 100}{m_d} =$	*20.41*	*20.60*	*20.79*
Average PLASTIC LIMIT $W_p = \dfrac{W_{p1} + W_{p2} + W_{p3}}{3} =$	*20.6 %*		

PLASTICITY INDEX

$$I_p = W_l - W_p = 32.1 - 20.6 = 11.5\ \%$$

Other important results

- % of particles smaller than 0.4 mm in the total sample = *98 %*

- % of particles smaller than 0.002 mm in the total sample = *2 %*

- % of particles smaller than 0.002 mm in the < 0.4 mm sample = *2.27 %*

Methylene blue test

Compressed earth blocks : testing procedures

METHYLENE BLUE TEST

1. General

1.1. Object of the test

The test measures the capacity of the fines in a soil to adsorb methylene blue on the internal and external surface of the particles under study. Taking the measurement of the quantity of methylene blue needed to cover with a monomolecular layer the external and internal surface of the constituent elements of the sample and of the mass of this sample, one determines a methylene blue value proper to the fraction studied to which the specific area of this fraction can be linked.

This test is therefore particularly suitable for studying clays or the clay fractions of a soil, since – depending on their mineralogical composition – these have specific areas which may vary in size.

To take one example, an identical quantity of montmorillonite type clay may have a specific area which is 20 times greater than that of a kaolinite type clay.

1.2. Principle of the test

Doses of ■ methylene blue solution are injected one after the other into the aqueous solution containing the fraction under study.

The adsorption of the methylene blue is checked 1 minute after each addition, by allowing ■ drop to fall on a filter paper.

A colourless ring indicates that all the blue injected has been adsorbed, and ■ blue ring, that saturation limit of adsorption has been reached.

2. Apparatus and products

2.1. Special apparatus

- A 100 ml or 50 ml capacity burette graduated every 1/10 ml or 1/5 ml, or a 5 ml and a 2 ml micro-pipette.
- Filter paper: quantitative and ash content < 0.01%; mass: 95 g/m^2; thickness: 0.20 mm; filtration speed: 75; retention diameter: 8 mm.
- A glass rod 300 mm long and 8 mm in diameter.
- A stirrer with mixer spindle, turning at between 400 and 700 r.p.m. The diameter of the spindle plates is between 70 mm and 80 mm.

2.2. Products

- Solution of medicinal quality methylene blue at 10 g/l ± 0.1 g/l. The maximum time limit for using the solution is 1 month and it should be stored away from any source of light and heat.
- Demineralised or distilled water.

2.3. Apparatus in common use

- A balance readable to 200 g and accurate to 1/100 gram.
- Stop watch showing seconds.
- 500 ml wash bottle.
- A 250 ml beaker.
- If necessary, a 3 l plastic beaker with a diameter of 155 mm and a 0.08 mm or 0.1 mm square mesh sieve if the sample has not been obtained from particle size analysis by wet sieving.

3. Preparing the sample

-   The test is carried out on the fraction of the material passing the 0.08 mm or the 0.1 mm sieve. The passing fraction from wet sieving with ▪ 0.08 mm or 0.1 mm mesh can therefore be retrieved (see procedure for particle size distribution by sieving) or prepare a new sample.
-   30 g of these dry particles of less than 0.08 mm or 0.1 mm are placed in the beaker, mixed with 100 cm^3 of demineralised or distilled water.
-   The mixer spindle stirrer is inserted into the suspension to subject the sample to continuous stirring for 5 minutes at 600 r.p.m., followed by stirring at 400 r.p.m. for the entire duration of the test, the mixer blades being located 1 cm above the bottom of the beaker.

4. Test procedure et Calculations

4.1. Test procedure

-   Successive doses of 5 cm^3 (or 5 ml) of the 10 g/l solution of methylene blue are injected.
-   Wait one minute following each injection of ▪ dose of methylene blue, and then using the glass rod, extract a drop of water and deposit it onto a filter paper. The ring which is formed as a result is made up of ▪ central deposit of material, of a generally deep blue colour, surrounded by a moist area forming ▪ colourless outer ring. While this outer ring is colourless, the methylene blue has been entirely adsorbed by the material and the test is negative. When the outer ring colours either totally or partially and consistently in a light blue colour, the test is said to be positive. The drop extracted should be such that the diameter of the deposit is between 8 and 12 mm.
-   If the test is positive (i.e. the outer ring begins to take on ▪ blue tinge), the adsorption of the methylene blue on the clayey fractions is left to continue without adding anything further, whilst at the same time carrying out tests at one minute intervals. If after 5 minutes, the test is still positive (persistent blue outer ring), the dosage is considered to be complete, as this suggests that the methylene blue has entirely covered the surface (external and internal) of the particles of the sample.
-   If the test is negative (i.e. the outer ring once more becomes colourless before the fifth stain, or before 5 minutes), the injections of methylene blue continue but in doses of 2 cm^3 every minute, until the test is positive for 5 consecutive minutes.
-   The total quantity of solution of blue (V_L) is recorded and the methylene blue value is calculated for the fraction in question.

4.2. Calculations

The quantity of methylene blue in grams adsorbed by 100 g of fines is called the "methlyene bleu value of the fraction between zero and d mm" (MB (0/d)).

If the solution of methylene blue is respected at 10 g per litre, the calculation can be simplified as follows: divide the total volume in cm^3 of solution of methylene blue injected by the dry mass of the sample in grams :

$$VB\ (0/d) = \frac{\text{total quantity of methylene blue injected } (V_L \text{ in } cm^3)}{\text{mass of dry sample } (m_d \text{ in g})}$$

-   Given that the molar mass of methylene blue = 373 g/mol and the surface area occupied by a molecule of methylene blue is 130 $Å^2$ or $130 \cdot 10^{-20}$ m^2, the total specific area of the fraction concerned can be calculated as follows:

Total specific area (0/d) or SST (0/d)

$$= \frac{VB(0\ /\ d)}{100} \times \frac{N}{373} \times 130 \times 10^{-20} \approx 21\ VB(0\ /\ d)$$

where N : Avogadro's number $= 6.023 \cdot 10^{23}$ (mol^{-1})

-   The main area of interest is the total specific area of the clays (< 2 µm) as the effect of the silts (> 2 µm) is negligible on the total specific area of the total sample.

The percentage of clays (particles smaller than 2 µm) in the fraction in question can be calculated as follows: $A = \dfrac{X}{T}$

the total specific area is then deducted from the particles smaller than 2 µm (SSTF) $SSTF = \dfrac{SST\,(0/d)}{A} \left[\dfrac{m^2 \cdot g^{-1}}{\%} \right]$

- The methylene blue value of the whole soil (or of the 0/d fraction) is then calculated :
  MBS or MB(0/D) = MB(0/d) x T
  Giving the total specific area of the total soil ($SST_{total\ soil}$):
  $SST_{total\ soil}$ = 21 MBS (or MB(0/D))

5. Reporting of results

Calculation form (see following page).

6. References

- TRAN NGOC LAN, "*Un nouvel essai d'identification des sols. L'essai au methylene blue*", in *Bulletin de liaison du LCPC*, 88, March - April 1977, Paris, France, 1977.
- AFNOR Standard P18-592, July 1980, "*granulats, essai au bleu de méthylène*".

TEST RESULTS FORM : METHYLENE BLUE

SAMPLE:	*red clayey sand N° 4B*	ORIGIN: *XY*
OPERATOR:	*NN*	LABORATORY: *YZ*
DATE :	*21/06/00*	

FRACTION CONCERNÉE : 0/d (mm)
where d = maximum diameter of particles in mm =

$d = 0/ 0.08\ mm$

DRY SAMPLE MASS: m_d (g)

$m_d = 30\ g$

	5 cm³ Injection	2 cm³ Injection	OUTER RING TEST blue outer ring: + : yes − : no				
			1 min	2 min	3 min	4 min	5 min
1	X		−				
2	X		−				
3	X		−				
4	X		+	+	+	−	
5		X	+	+	+	−	
6		X	+	+	+	+	+
7							
8							
9							
total of injections	4	2					
total in cm³	20	4					
total injection in cm³	= V_L	24					

METHYLENE BLUE VALUE FOR THE FRACTION IN QUESTION

$MB(0/d) = \dfrac{V_L}{m_d} \Rightarrow \dfrac{24}{30}$

$MB(0/\ 0.08\ ) = 0.8$

TOTAL SPECIFIC AREA FOR THE FRACTION IN QUESTION

SST (0/d) = 21 MB (0/d) ☐

$SST(0/\ 0,08\ ) = 16,8\ \dfrac{m^2}{g}$

Reminder of other important values:

% of the fraction in question (0/d) across the total sample (see particle size distribution test by wet sieving) (T) =

$T = 31\%$

% of particles smaller than 2 μm in the total sample (X) =

$X = 17.8\ \%$

% of particles smaller than 2 μm in the fraction in question
$A = \dfrac{X}{T}$

$A = 57.4\ \%$

Total specific area of particles smaller than 2 μm (SSTF) =
$SSTF = \dfrac{SST(0/d)}{A} \left[\dfrac{m^2 \cdot g^{-1}}{\%} \right]$

$SSTF = 29,3\ \dfrac{m^2}{g}$

Methylene blue value of the total soil (or fraction 0/D) =
MBS or MB(0/D) = MB(0/d) x T = $0.8 \times 0.31 =$

$MBS = 0.25$

Total specific area of the total soil =
$SST_{total\ soil}$ = 21 MBS or MB(0/D) = $21 \times 0.25 =$

$SST_{ts} = 5.25\ m^2/g$

Compressed Earth Blocks: testing procedures

Organic matter content test

ORGANIC MATTER

1. General

1.1. Object of the test

Soils may contain organic matter (micro-organisms, humus, etc.). Some humid acids (particularly fluidic acid) are harmful in the event of stabilisation, as they delay or prevent the setting of hydraulic binders. As it is not possible to compress the composition of organic matter, it is to be avoided in too great ■ proportion as this would significantly reduce the compressibility of the soil, even if it were non-stabilised.

The test allows the organic matter content of a sample to be identified. Various procedures exist, notably chemical analyses, but these, however, require very specialised equipment and are relatively cumbersome or imprecise.

1.2. Principle of the test

The procedure consists in heating the soil sample to a high temperature (400°C) in order to calcine the organic matter and thus to obtain its mass and therefore its percentage in dry mass.

If it is not possible to heat the sample to such a high temperature, we recommend a basic test which allows one to make ■ qualitative judgement of the presence of organic matter, by wetting the sample, which accentuates the strong smell which organic matter gives off. If the soil gives off a smell, this would suggest ■ significant presence of organic matter and the soil should not be used for CEB production, stabilised or not.

2. Apparatus

2.1. Special apparatus

- Ventilated drying oven capable of being maintained at a temperature of 105°C.
- Oven reaching a temperature of 400°C.
- A balance readable to 600 g and accurate to 1/10 gram.

2.2. Apparatus in common use

- Evaporating dishes compatible with the sample quantity and resistant to the temperature of the drying oven and of the higher temperature oven.

3. Preparing the sample

The mass (m, expressed in g) of an intact or disturbed soil for which one wishes to determine the organic matter content is decided in the light of the size of the coarsest elements that the soil contains (D, expressed in mm).

If the size of the grains is less than 0.4 mm, the mass of the test sample should be such that $m \geq 10\,D$.

If the size of the grains is greater than or equal to 0.4 mm, the mass of the test sample should be greater than 20 g with in addition $m \geq 200D$. In this event, the maximum size of the coarsest elements is assessed visually.

4. TEST PROCEDURE AND CALCULATIONS

4.1. Test procedure

- Decide the quantity of test sample required.
- Select the appropriate sized evaporating dish.

- Measure the evaporating dish mass (m_t, expressed in g).
- Place the evaporating dish containing the sample in the ventilated drying oven set to 105°C for 24 hours.
- Measure the mass of the evaporating dish including the dry sample (m_{td}, expressed in g)
- Return the evaporating dish to the oven for 2 hours.
- Checking the drying: measure the mass of the evaporating dish. If the mass shown is the same as the mass measured before, then this is indeed the dry mass. If not, return the evaporating dish once again until ∎ constant mass is obtained.   The mass will regarded as constant when two successive weightings carried out at a 24 hour interval show a loss of mass of < 0.1 % of the initial mass.

Note :   A micro-wave oven may be used, in which case the drying time will be 15 minutes (instead of 24 h) and the drying shall be checked between 3 and 5 minutes (instead of 2 h).
- Place the evaporating dish in an oven at 400°C for 3 hours.
- Let the oven cool.
- Measure the mass of the evaporating dish including the heated sample (m_{tc}, expressed in g).

4.2. Calculations

- mass of dry solid grains (m_d, expressed in g):
$m_d = m_{td} - m_t$

- quantity of organic matter contained in the sample (m_o, expressed in g):
$m_o = m_{td} - m_{tc}$

- organic matter content:
if T_o >1%, this is risky and if T_o >2% the soil should not be used if there is incompatibility with any stabiliser used.
$$T_o(\%) = \frac{m_o \times 100}{m_d}$$

5. Reporting of results

See following page.

TEST RESULTS FORM : ORGANIC MATTER CONTENT

SAMPLE:	*red clayey sand N° 4B*	ORIGIN: *XY*
OPERATOR:	*NN*	LABORATORY: *YZ*
DATE :	*21/06/00*	

Determining the mass of the test sample

- mass of test sample : m
- size of the coarsest elements contained in the soil

$D = 5\ mm$

$$\underline{D < 0.4\ mm\ ?}$$
$$\downarrow$$
$$m \geq 10\ D$$
$$\Downarrow$$

m =

$$\underline{D \geq 0.4\ mm\ ?}$$
$$\downarrow$$
$$m > 20\ g\ et = m \geq 200\ D$$
$$\Downarrow$$

m = *1000 g*

Determining the organic matter content

evaporating dish number	*5 g*
evaporating dish mass = m_t (g)	*152 g*
evaporating dish mass + dry sample = m_{td} (g)	*924 g*
evaporating dish mass + sample heated to 400°C = m_{tc} (g)	*920 g*
mass of dry solid grains = m_d (g) = $m_{td} - m_t$	*772 g*
mass of organic matter = m_o (g) = $m_{td} - m_{tc}$	*4 g*
organic matter content = $T_o(\%) = \dfrac{m_o \times 100}{m_d}$	*0.52 %*

Check: $T_o < 2\%$?   YES ■
                 NO ☐

PRODUCTION TESTS

Optimum water content test

Compressed earth blocks : testing procedures

1. General

1.1. Object of the test

This test enables one to determine the capacity of a soil to be compacted as a result of a variable compacting force applied directly using a given CEB production press.

1.2. Principle of the test

A soil sample is subjected to static compaction at different water contents and at the compaction force of a given static press. For each water content, the dry density is measured.

This allows one to observe that for a given type of press using static compaction and ■ given soil, there is ■ quantity of soil and an optimum water content which enables one to obtain a maximum dry density. A CEB with maximum dry density will have maximum mechanical strength.

It is important to distinguish between two types of compaction depending on the presses used:

1.2.1. Presses delivering a set force:

The pressure generated by ■ thermal (or electric) motor which is regulated by valves is applied by a hydraulic jack. The force applied in the mould box of such presses is virtually independent of the quantity of material introduced. It depends solely on the control and regulation mechanisms proper to each material (pressure cut-off device, power-assisted valves, etc.)
Achieving optimum block production with these presses is simple since this depends solely on the water content of the material used (see Test procedure).

1.2.2. Presses delivering a set displacement:

In the case of manual or mechanical presses, the compressive force is obtained by the displacement of ■ piston on an set course.

For manual presses, the lever travels its course until it reaches ■ stop.
In the case of manual presses, if too much material is introduced into the mould box, the press lever will not be able to travel to the end of its course and consequently the block will not receive maximum compaction.
Achieving optimum block production with these presses therefore depends both on the water content of the material used and on the quantity of material introduced (see Test procedure).

For mechanical presses, the displacement of the piston occurs thanks to ■ cam or a manual connecting rod system, driven by an engine. An elastic system made up of springs is part of the mechanism, preventing the engine from stalling in the event of the mould box being overfilled. If the springs are activated, this means that part of the displacement of the piston and therefore of the force applied is being absorbed by the springs rather than by the soil. In practice, one must avoid over-using the springs, since this is likely to cause major variations in the height of the blocks produced.
Compression may also be single or double action.

For these presses to work well, each stage must be fully completed before triggering the following stage. For example, it is very important for the piston to travel its entire course, resulting in both maximum compaction and in the block produced being ejected from the mould.

2. Apparatus

2.1. Specific apparatus

- Press for compressed earth blocks

2.2. Apparatus in common use

- Hotplate, stove, oven (for calculating water content)
- A balance readable to 600 g and accurate to 1/10 gram.
- A balance readable to 10 kg and accurate to 1 gram (for calculating dry densities)
- A wheel barrow
- A spade
- Buckets of water
- A rule
- A short-handled brush

3. Preparing the sample

The samples prepared for carrying out this test must be homogenous and will be representative of the material tested. Each sample will have a mass of approximately 100 kg.

4. Test procedure and calculations

4.1. Test procedure

4.1.1. Press using set displacement (generally manual or mechanical):

1. Prepare approximately 100 kg of wet material at a water content in the order of W = 6 to 9 %.
2. Fill the press mould box.
3. Carry out a complete cycle of compaction and removal from the mould with the lever, thus using the press to produce a block.
4. Measure its mass (m_h in g) and its dimensions (length L, width w and height h in cm).
5. Calculate its dry density $\dfrac{\rho_d}{\rho_W} = \dfrac{100 \times m_h}{L \times w \times h \times (100 + W)}$
6. Introduce into the mould box a quantity of wet material with a mass 100 g greater than the preceding one (taking care that all the material is inside the mould).
7. Repeat operations 3, 4, 5 and 6 until it is no longer possible to carry out a complete cycle of compaction and removal from the mould using the press (the piston being unable to travel to the end of its course).
8. Prepare approximately 100 kg of the material at a water content of approximately 1 to 2 % more than the preceding material and repeat operations 2 to 7 until the blocks obtained are too wet (visually) on removal from the mould.
9. Trace the dry densities obtained on a diagram (see diagram below).
10. By observing this diagram, one can determine the water content and the quantity of material required to produce blocks at their optimum.

4.1.2. Presses using set force (generally hydraulic):

1. Prepare approximately 100 kg of wet material at a water content in the order of W = 6 to 9 %.
2. Make 3 to 4 blocks using the press.
3. Measure the mass (m_h in g) and the dimensions of each block (length L, width w and height h in cm).
4. Calculate the dry density of each block $\dfrac{\rho_d}{\rho_W} = \dfrac{100 \times m_h}{L \times w \times h \times (100 + W)}$

Compressed Earth Blocks: testing procedures

6.   Prepare approximately 50 kg of the material at a water content of approximately 1 to 2 % more than the preceding material and repeat operations 2 to 5 until the blocks obtained are too wet (visually) on removal from the mould.
7.   Trace the dry densities obtained on ■ diagram (see diagram below).
8.   By observing this diagram, one can determine the water content and the quantity of material required to produce blocks at their optimum.

4.2. Calculations

Dry density of a block: $\dfrac{\rho_d}{\rho_W} = \dfrac{100 \times m_h}{L \times w \times h \times (100 + W)}$

5. Reporting of results

Calculations form and graphs (see following page).

6. References

- Compressed earth blocks: production equipment – Series Technologies N° 5, Houben H., Rigassi V., Garnier P.; CDI, CRATerre-EAG, Brussels / Villefontaine, Belgium / France, 1994.
- *Comportement des sols fins argileux pendant un essai de compactage statique : détermination des paramètres pertinents*, Mesbah A., Morel J.C., Olivier M., *Matériaux et construction*, vol. 32, n° 223, Nov. 1999.

TEST RESULTS FORM: OPTIMUM WATER CONTENT

| SAMPLE:	*red clayey sand N° 4B*	ORIGIN: XY
OPERATOR:	NN	LABORATORY : YZ
DATE :	21/06/00	

|	BLOCK 1	BLOCK 2	BLOCK 3	BLOCK 4	BLOCK 5	BLOCK 6
Max. compactable mass of block m_h (kg)	7.7 kg	7.8 kg.	7.9 kg	7.9 kg	7.9 kg	7.8 kg
Estimated water content (%)	10.5 %	11.5 %	11.5 %	12.5 %	13.5 %	13.5 %
Calculated water content W (%)	10.48 %	11.05 %	11.72 %	12.33 %	13.66 %	14.29 %
Length L (m)	0.295	0.295	0.295	0.295	0.295	0.295
Width w (m)	0.140	0.140	0.140	0.140	0.140	0.140
Height h (m)	0.096	0.096	0.096	0.095	0.0955	0.096
Volume V (m^3)	0.003965	0.003965	0.003965	0.003924	0.003944	0.003965
Dry density (kg/m^3) $$\rho_d = \frac{100 \times m_h}{V \times (100 + W)}$$	1757.9	1771.5	1783.6	1792.5	1762.3	1721.4

Achieving optimum production water content and mass dry density (kg/m3)

Compressed Earth Blocks: testing procedures
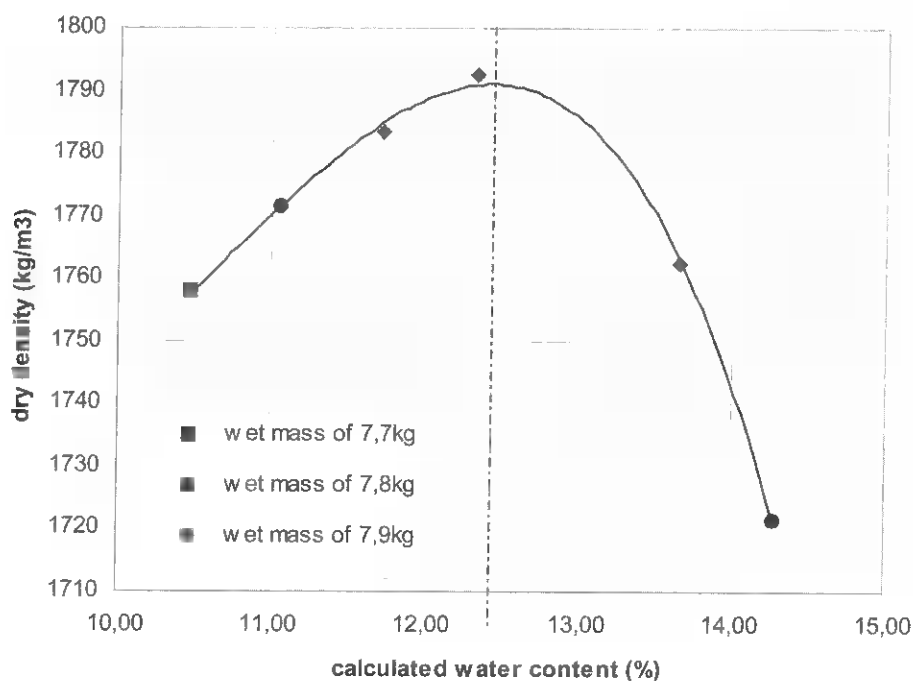
FINISHED PRODUCT TESTS
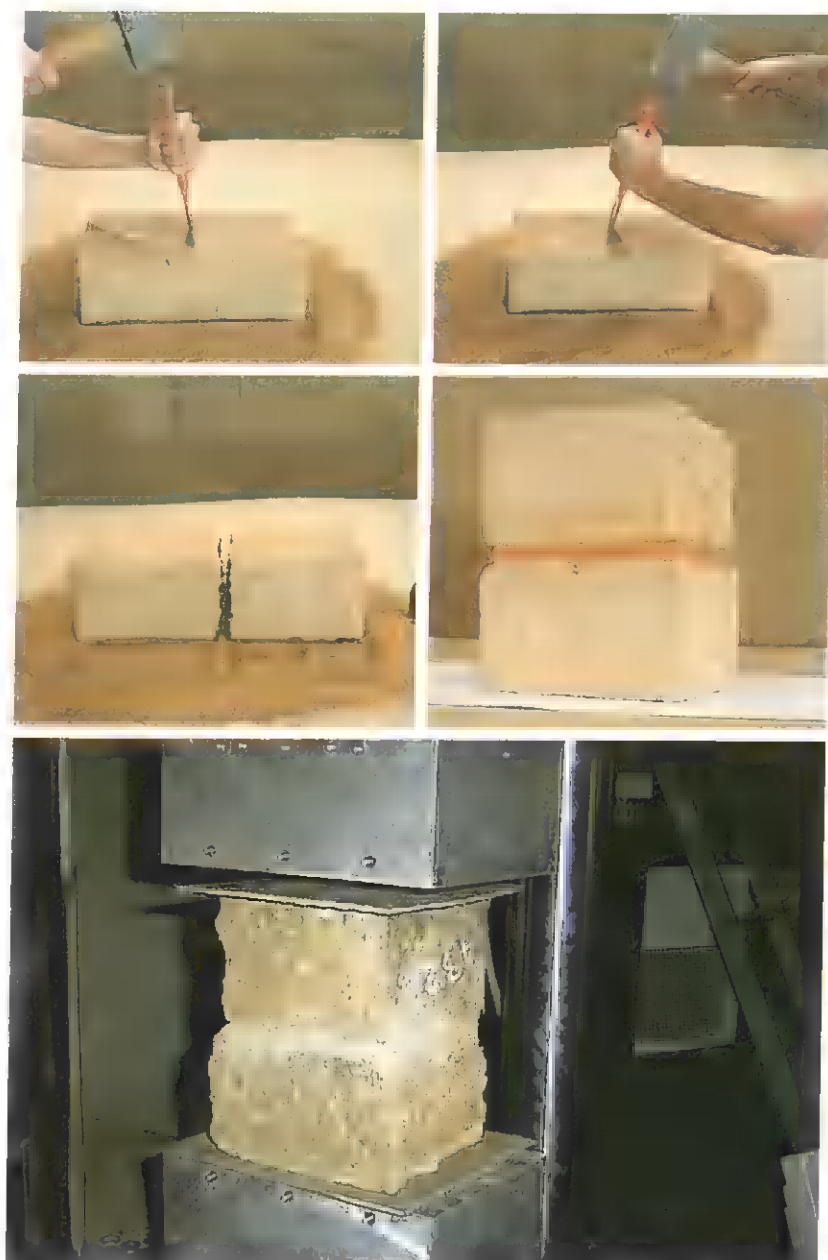
Dry compressive strength test

DRY COMPRESSIVE STRENGTH

1. General

For the past twenty years or so, compressed earth blocks have provided a new alternative to building materials such as concrete or fired bricks.

Although the methodology of block production is now well understood and materials have been designed to enable one to obtain a reliable, high performance material, there is not yet a universally recognised test standard to assess the compressive and the tensile strength of these blocks.

The object of the present section is to suggest an operational method for carrying out mechanical compression tests on parallelepiped blocks of compressed unfired earth.

The tests have been devised to be carried out on cylindrical test samples.

1.1. Object of the test

To determine the dry compressive strength of blocks intended for masonry in order to obtain comparative results regardless of the configuration of the block.

1.2. Principle of the test

The test consists in subjecting a sample to simple compression until failure, the sample being made up of two half-blocks placed one on top of the other and stuck together using a mortar made of earth or alternatively of sand cement, in the case of stabilised CEBs.

The half-blocks, which shall be full, are crushed in the direction in which they are laid by the effect of a constant displacement or ■ constantly increasing load provided by a press.

The crushing is considered to be complete at the moment of complete failure. One can thus calculate the compressive strength of the block (f_b dry).

To avoid problems relating to uneven contact points, both faces of the specimen are faced with a cement paste or sheets of cardboard or plywood.

The minimum height of the block shall be 6 cm.

2. Apparatus

2.1. Special apparatus

-       A calibrated crushing press for hard materials (in particular the flatness of the loading plates and the centre of application of loads must have been checked); it is preferable to be able to adjust the speed of displacement of the plates so that the block does not fail in the first fifteen seconds of the test, and the power should be should be compatible with the strength of the blocks[*].

---

[*] Minimal capacity of the press assuming the following data:
-       standard half-block measuring approximately 14.7 x 14 x 10 cm,
-       compressed surface area: approximately 200 cm^2,
-       the press shall allow compression at a pressure in the range 1MPa et 20 MPa,
-       the block shall not fail in the first fifteen seconds.

Thus the capacity of the press will fall in the range 20 to 400 kN and the dial should enable precise readings to be taken between these two margins.

The rhythm of the press should enable the set displacement to be adjusted to the nearest 0.02 mm/sec.

The press should enable the increase in load to be adjusted to between 0.15 et 0.25 MPa/s. Mechanical data: tempered steel: 55 [RC] (Rockwell); depth of tempering: 5 mm; French standard NFP 18 412.

2.2. Apparatus in common use

- Ventilated drying oven capable of maintaining a temperature of 40°C ± 5° C;
- precision rule graduated in mm;
- a balance readable to 10 kg and accurate to 1 gram. For masses > 10 kg accuracy of ± 5 g is permissible;
- a mallet and a knife or blade to make two half-blocks;
- 0/3 mm sand, high alumina melted cement (CA) and artificial Portland cement (CPA-CEM I) ;
- if necessary two sheets of smooth cardboard or plywood, 3 or 4 mm thick;
- a flat surface: a sheet of metal or of glass, which has been checked beforehand for flatness (deviation from flat when loaded less than 0.30 mm);
- oil to assist removal from the mould or film of plastic material which does not stick to the cement paste (polythene for example).

3. Preparing the sample and making the specimen

3.1 Preparing the sample

- The blocks are of a homogenous structure and shall have no cracks visible to the naked eye.
- Dry compressive strength tests are carried out on dry blocks. Oven-dry the block to 40° C until ■ constant mass is obtained (the mass of the block is constant when the difference in mass does not exceed 0.1% between 2 weighings at a 24 h interval).
- Remove the block from the oven and leave it to stand for approximately 2 hours.
- Wipe the block to remove any dust or loose matter stuck to the block.
- The samples selected from the blocks should each have an identical dry density, only a variation of maximum 1% is permissible between blocks of the same sample group.

3.2. Making the specimen

- Cut the blocks in two. To do this, ■ tensile strength test (see below, pp. 73 - 76) can be carried out beforehand.
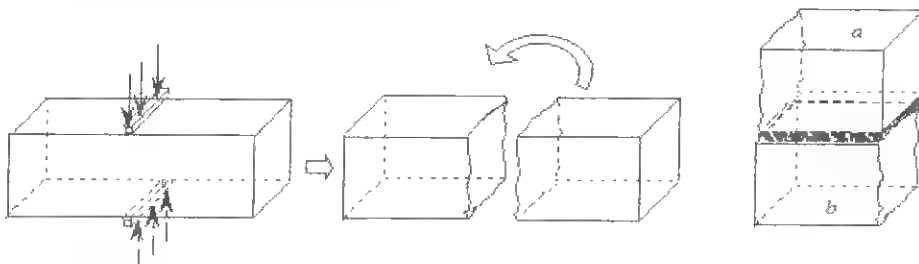
Alternatively, cut each block across the middle by sawing it into two equal pieces or break the blocks as follows:
- Place the block on a bed of fine sand, make ■ groove on the four sides showing where it should break. Place a steel blade on one of the grooves and hit it with a mallet to obtain the two half-blocks.
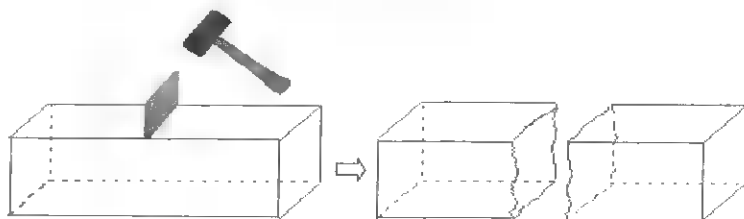
- Wet the laying face of the two half-blocks, and place the two corresponding halves of each block one on top of the other, taking care that the header of one should be on the same side as the cut section of the other, with an intermediate layer of mortar no more than 10 mm thick. The mortar is made of a mix of 0/3 mm sand and of Portland cement dosed at 1 volume of cement for 5 volumes of sand, so that the test can be carried out after 48 hours' curing.

Compressed Earth Blocks: testing procedures

NOTE
It is also possible to use an interface mortar made of ■ material similar to that used to produce the CEBs (soil, if necessary with added sand) for unstablised blocks intended for use in a dry environment.
For stabilised blocks intended to be used in a wet environment, the mortar will also be made of a material similar to that used for the production of the CEBs, consisting of soil, if necessary with added gravel and cement, so that the compressive strength of the mortar is ± the same as that of the blocks.

The following procedure is recommended:
-    remove all loose material from the laying face and the bed face;
-    partially immerse the laying face in 1 to 2 cm of water for a quarter of an hour. Repeat the same operation for the bed face;
-    spread the mortar to ■ thickness of approximately one centimetre on the laying face of the first half-block;
-    lay the bed face of the second half-block as if building the wall, taking care that the entire surface of the laying face is loaded with mortar;
-    check that the two half blocks are parallel using the materials testing press to apply a very slight load to the specimen before the interface mortar sets;
-    leave to harden or to cure for at least 48 h before the compression test;

NOTE
For unstablised blocks, the mortar is simply left to dry and harden. For stablised blocks, the specimen should be hermetically sealed and left to cure for 48 h.

Laying the two half-blocks one on top of the other

-    once the mortar has set and hardened, measure the dimensions of the upper and lower surfaces of the resulting specimens and calculate for each of them the average of the two surfaces.

3.3. Coating the specimen

-    Coat the upper and lower faces of each specimen using a pure mortar paste. The mortar is made of a mix of high alumina melted cement (CA) and Portland cement (CPA-CEM I) in a proportion at which it sets within a maximum time of 10 to 15 min.
The pure paste is generally made up of 2/3 Portland cement and 1/3 high alumina melted cement to a maximum thickness of 3 mm.
The following procedure is recommended:

-    remove all loose material from the laying face and the bed face;
-    partially immerse the laying face in 1 cm to 2 cm of water for a quarter of an hour.
-    spread the paste on the flat surface (to which ■ product to assist removal from the mould has first been applied);
-    place the block as it would be in the wall being built, taking care that the entire laying face is loaded with paste, and check that the free surface is parallel to the flat surface;
-    leave to harden for approximately 15 min and repeat the same operation by turning the block over onto the opposite face, so that the bed face is coated following partial immersion as described above;
-    coating should occur at least 12 h before the compression test.

NOTE
It is possible to use another type of surface coating (sheets of smooth cardboard or of plywood, 3 or 4 mm thick) but in this event this should be recorded in the results.

4. Test procedure and calculations

4.1. Test procedure

- Centre the complete specimen between the plates of the press, so that the geometric centre of the loaded surface is located on the axis of the plate to the nearest ± 1 mm .
  Monitor that it is centred by checking on all four sides the distances between the edges of the speciment and the sides of the plates using ■ ruler.
- Apply the load in a continuous manner, with no sudden jolts, at a regular speed of 0.02 mm/s, or corresponding to an increase in pressure of between 0.15 and 0.25 MPa/s until complete failure of the specimen. No adjustment should be made to the test machine controls immediately before the failure.
- Record the maximum load borne by the specimen during the test.

4.2. Calculations

The compressive strength of the blocks is shown by the formula $f_b dry = 10 \times \dfrac{F}{S}$

in which:

f_b dry: dry compressive strength of the blocks in Mega Pascals (MPa) or (MN/m²) or (N/mm^2).

F : maximum load borne by the two half-blocks in kilo Newtons, (kN).

S: average surface area of the test faces in square centimetres (cm^2) (as the surfaces are not always regular, the common surface in contact is used).

The average compressive strength of the blocks is the arithmetic average of the compressive strengths of at least three tests carried out on specimens from the same lot.

5. Reporting the results

Calculations form (see following page).

6. References

- NBN/B 24-301 *Projet de norme Belge concernant l'approche et le calcul de maçonnerie*, 1976.
- ENTPE geomaterials laboratory: A. Mesbah, Z. El Gharbi, M. Olivier, *Proposition d'une norme pour la réalisation d'essais de résistance sur BTC.* Vaulx-en-Velin, France, September 1995.

TEST RESULTS FORM : DRY COMPRESSIVE STRENGTH

SAMPLE :	*Red blocks*	ORIGIN : *XY*
OPERATOR :	*NN*	LABORATORY : *YZ*
DATE :	*21/06/00*	

TYPE OF TEST : dry strength ■
wet strength ▢

	SPECIMEN 1	SPECIMEN 2	SPECIMEN 3
AGE OF BLOCKS	*3 weeks*	*3 weeks*	*3 weeks*

DIMENSIONS OF SPECIMENS	SPECIMEN 1		SPECIMEN 2		SPECIMEN 3	
	Lower dimensions	Upper dimensions	Lower dimensions	Upper dimensions	Lower dimensions	Upper dimensions
Length (L) in cm	*14.5*	*14.5*	*14.5*	*14.5*	*14.5*	*13.6*
width (w) in cm	*14*	*14*	*14*	*14*	*14*	*14*
Surface area (L x w) in cm^2	*203*	*203*	*203*	*203*	*203*	*190.4*
Average surface area (S) in cm^2	*203 cm2*		*203 cm2*		*196.7 cm2*	

TYPE OF LOAD	*Constant displacement*	*0.02 mm/seconds*

CRUSHING	SPECIMEN 1	SPECIMEN 2	SPECIMEN 3
Crushing time	*21 seconds*	*21 seconds*	*20 seconds*
Breaking load (F) in kN	*62.3 kN*	*60.8 kN*	*61.0 kN*
Compressive strength (dry or wet) of the blocks f_b dry / wet $= 10 \times \dfrac{F\,(kN)}{S\,(cm^2)}$	*3.069 MPa*	*2.995 MPa*	*3.101 MPa*
Average dry compressive strength of the blocks f_b dry	*3.06 MPa*		
Average wet compressive strength of the blocks f_b wet	*/*		

PARTICULAR CURING CONDITIONS

The blocks come straight from the production unit where they have been stored for 7 days under plastic and for 2 weeks in the open.

Wet compressive strength test

Compressed earth blocks : testing procedures
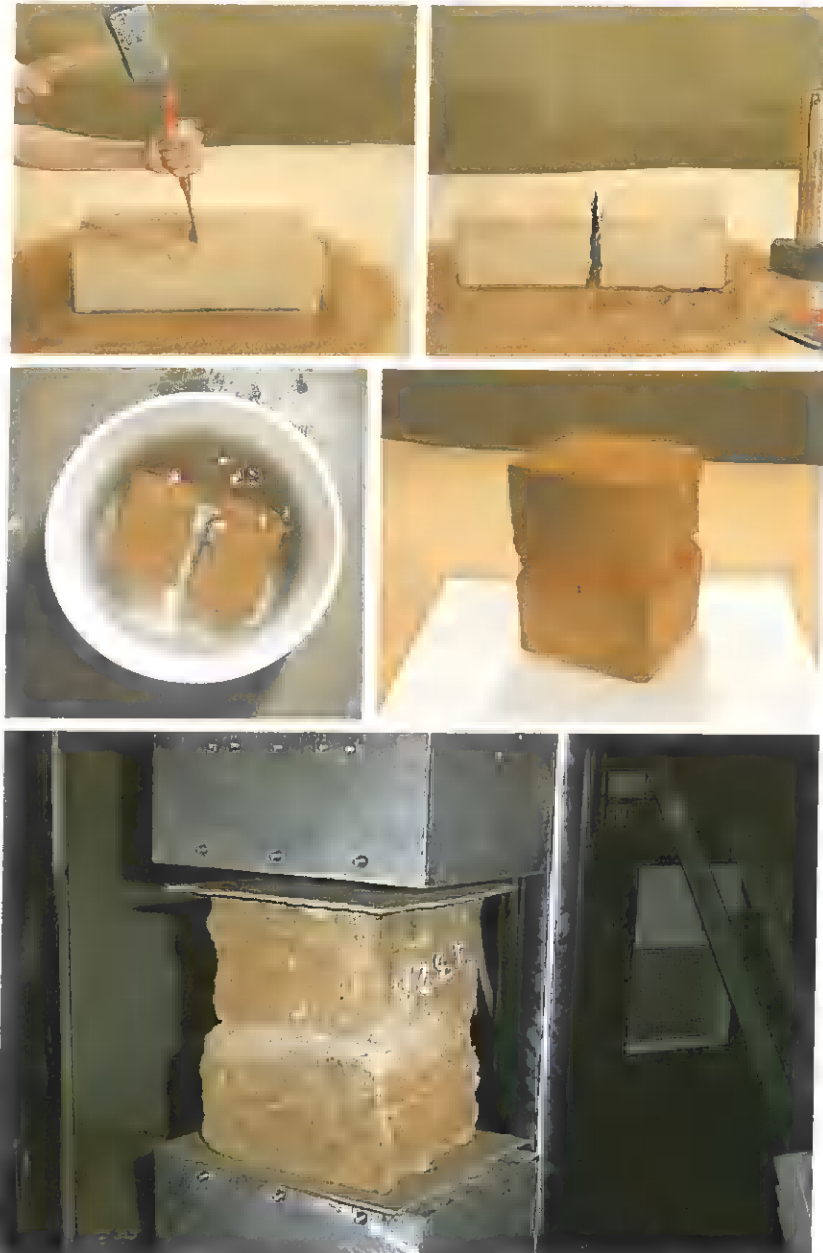
WET COMPRESSIVE STRENGTH

1. General

Buildings are often exposed to the effects of water, particularity as ■ result of capillarity and of spraying; by contrast, they are rarely submerged.

The mechanical characteristics (tensile and compressive strength) of wet blocks are weaker than those of dry blocks. It is therefore useful to test them in a wet state in order to be aware of their minimum characteristics in worst case circumstances. If the characteristics of the wet blocks prove unsatisfactory, they can be improved, e.g. by increasing the proportion of binder, or by selecting the soil and/or the type of hydraulic binder used more carefully.

The blocks can be made wet as a result of immersion or capillarity. The test for capillary absorption (described below in this section, pp. 83-85) is a reasonable approximation of what happens in reality, but immersion has the advantage of being quick and simple to carry out.

The object of the present section is to suggest an operational method for carrying out mechanical compression tests on wet CEBs. These tests have been adapted from the operational methods for dry compressive strength tests.

1.1. Object of the test

To determine the wet compressive strength of blocks intended for masonry subject to a wet environment in order to obtain comparative results regardless of the configuration of the block.

1.2. Principle of the test

This test is identical to the dry compressive strength test, except that the specimen is wet by complete immersion for 2 hours.

The crushing is considered to be complete at the moment of complete failure. One can thus calculate the wet compressive strength of the block (f_b wet).

The minimum height of the block shall be 6 cm.

2. Apparatus

The apparatus is identical to that used for the dry compressive strength test, apart from an additional tray enabling the specimens to be completely immersed, and a watch to monitor the time of submersion (2 h.).

3. Preparing the sample, wetting and making the specimen

3.1. Preparing the sample

-       prepare the sample in exactly the same way as for the dry compressive strength test (see p. 64, § 3.1.).
-       cut the blocks in two as described for the dry compressive strength test (see pp. 64 - 65, § 3.2.).

3.2. Wetting the specimen

-       Place the half-blocks in a tray of clean water for two hours, ensuring that there is at least 5 cm of water above the upper faces of the blocks.
-       2 hours later remove the half-blocks and dry them with a sponge, a cloth or a chamois-leather.

3.3. Making the specimen

-       Place the two corresponding halves of the half-blocks one on top of the other as described for the dry compressive strength test (see p. 64-65, § 3.2.).

- check that the two half blocks are parallel using the materials testing press to apply a very slight load to the specimen before the interface mortar sets;
- if necessary, coat the specimen using a cement paste as described for the dry compressive strength test. Alternatively, use sheets of cardboard or of plywood when carrying out the test (see p. 65, § 3.3.);
- wrap the specimens prepared in this way in ■ hermetically sealed bag for at least 48 hours;
- after 48 h, measure the dimensions of the upper and lower surfaces of the specimens and calculate – for each specimen – the average of these two surfaces.

4. Test procedure and calculations

Use the same procedure as for dry compressive strength (see p. 66, § 4.)

5. Reporting the results

Calculations form (see preceding section on Dry compressive strength).

6. References

- NBN/B 24-301 *Projet de norme Belge concernant l'approche et le calcul de maçonnerie*, 1976.
- ENTPE Geomaterials laboratory: A. Mesbah, Z. El Gharbi, M. Olivier, *Proposition d'une norme pour la réalisation d'essais de résistance sur BTC.* Vaulx-en-Velin, France, September 1995.

TEST RESULTS FORM : WET COMPRESSIVE STRENGTH

SAMPLE :	*Red blocks*	ORIGIN : *XY*
OPERATOR :	*NN*	LABORATORY : *YZ*
DATE :	*21/06/00*	

TYPE OF TEST :	dry strength	❑
	wet strength	■

	SPECIMEN 1	SPECIMEN 2	SPECIMEN 3
AGE OF BLOCKS	*3 weeks*	*3 weeks*	*3 weeks*

DIMENSIONS OF SPECIMENS	SPECIMEN 1		SPECIMEN 2		SPECIMEN 3	
	Lower dimensions	Upper dimensions	Lower dimensions	Upper dimensions	Lower dimensions	Upper dimensions
Length (L) in cm	*14.5*	*14.5*	*14.5*	*14.5*	*13.8*	*14*
width (w) in cm	*14*	*14*	*14*	*14*	*14*	*14*
Surface area (L x w) in cm^2	*203*	*203*	*203*	*203*	*193.2*	*196*
Average surface area (S) in cm^2	*203 cm^2*		*203 cm^2*		*194.6 cm^2*	

TYPE OF LOAD	*Constant displacement*	*0.02 mm/seconds*

CRUSHING	SPECIMEN 1	SPECIMEN 2	SPECIMEN 3
Crushing time	*21 seconds*	*21 seconds*	*22 seconds*
Breaking load (F) in kN	*30.5 kN*	*31.2 kN*	*30.9 kN*
Compressive strength (dry or wet) of the blocks $f_b \text{ dry / wet} = 10 \times \dfrac{F\,(kN)}{S\,(cm^2)}$	*1.502 MPa*	*1.537 MPa*	*1.588 MPa*
Average dry compressive strength of the blocks f_b dry	*/*		
Average wet compressive strength of the blocks f_b wet	*1.54 MPa*		

PARTICULAR CURING CONDITIONS

The blocks come straight from the production unit where they have been stored for 7 days under plastic and for 2 weeks in the open. The half-blocks were immersed for 2h in the laboratory.

Dry tensile strength test

Compressed earth blocks : testing procedures
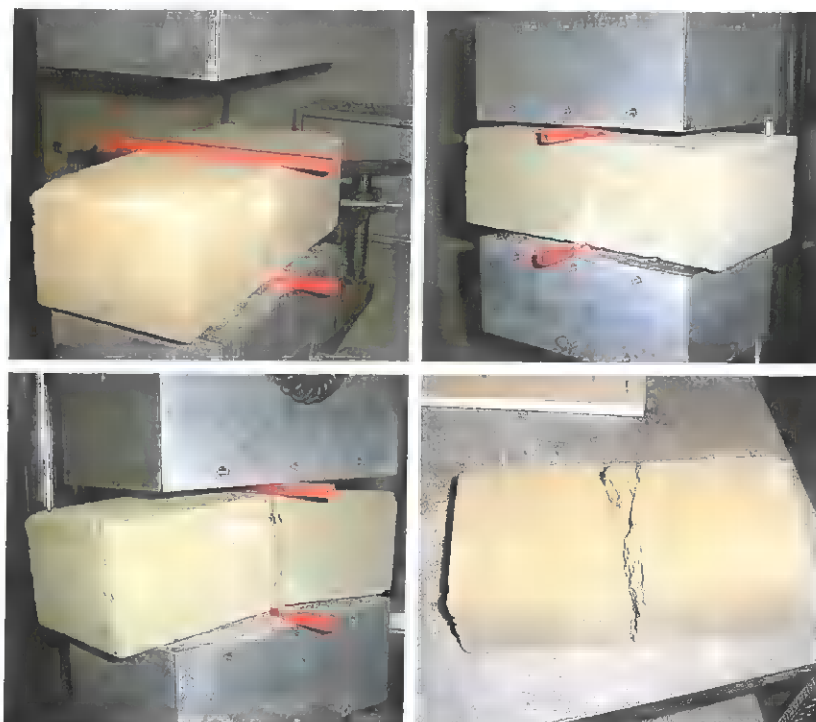
DRY TENSILE STRENGTH

1. General

Blocks used for masonry with mortar are subject to tensile stresses which can sometimes cause vertical cracking. The relation between compressive strength and tensile strength is not constant and is not known. It is therefore useful to measure the tensile strength of blocks thus obtaining ■ more precise characterisation of ■ given lot of CEBs.

The object of the present section is to suggest an operational method for carrying out mechanical tensile tests on parallelepiped blocks of compressed unfired earth.

The tests have been devised to be carried out on cylindrical specimens.

1.1. Object of the test

To determine the dry tensile strength of blocks intended for masonry in order to obtain comparative results regardless of the configuration of the block.

1.2. Principle of the test

This test derives from the splitting test (or Brazilian test). It involves subjecting the block to ■ compressive force along two rods located on each side of ■ block, which results in an average tensile stress along ■ vertical face passing between these two rods.

2. Apparatus

2.1. Special apparatus

- A crushing press which allows the speed of displacement of the plates to be adjusted and the power of which is compatible with that of the blocks[*],
- two rigid plastic or hard wood rods with a square section of 1 x 1 cm and slightly longer than the width of the block or of the specimen to be tested.

2.2. Apparatus in common use

- Ventilated drying oven capable of maintaining ■ temperature of 40°C,
- precision ruler graduated in mm,
- a balance readable to 10 kg and accurate to 1 gram. For masses > 10 kg accuracy of ± 5 g is permissible.

3. Preparing the sample

- The blocks shall be homogenous in structure and shall have no cracks visible to the naked eye.
- Dry tensile strength tests are carried out on dry blocks. Oven-dry the block at 40° C until a constant mass is obtained. The mass of the block is constant when the difference in mass does not exceed 0.1% between 2 weighings at a 24 h interval.
- Remove the block from the oven and leave it to stand for approximately 2 hours.

---

[*] Minimal capacity of the press assuming the following data:

- standard block measuring 29.5 x 14 x 10 cm,
- the press shall allow compression at ■ pressure in the range 1MPa and 20 MPa,
- the block shall not fail in the first fifteen seconds.

Thus the capacity of the press will lie between 20 and 400 kN and the dial should enable precise readings to be taken between these two margins.

The rhythm of the press should enable the set displacement to be adjusted to the nearest 0.02 mm/sec.

The press should enable the increase in load to be adjusted to between 0.15 et 0.25 MPa/s. Mechanical data: tempered steel: 55 [RC] (Rockwell); depth of tempering: 5 mm; French standards NFP 18 412.

- Wipe the block to remove any dust or loose matter stuck to the block.
- The blocks must be weighed (to the nearest 5g) and precisely measured (to the nearest 0.5 mm) before testing.
- The results of the tests must record the dimensions, the age and the dry density of the samples. The block destined for testing should have been made at least 3 weeks before.
- The samples selected from the blocks should each have an identical dry density, only a variation of maximum 1% is permissible between blocks from the same sample group.

4. Test procedure and calculations

4.1. Test procedure

- Make two rigid plastic or hard wood rods with a square section of 1 x 1 cm, and a little longer than the width of the block for testing,
- Place one rod in the middle of the press plate, the diameter of the supporting plate being greater than the width of the block,
- Place the block at the middle of its lower larger face on top of the rod; the block must remain balanced,
- Place the second rod parallel to the first on the upper face of the block, similarly, the diameter of the supporting plate being greater than the width of the block
- Apply the load in a continuous manner, with no sudden jolts, at a regular speed of 0.02 mm/s, until the sample breaks in two,
- Repeat the same operations for each of the two half-blocks previously obtained. Three tensile strength values can thus be obtained from a single block.
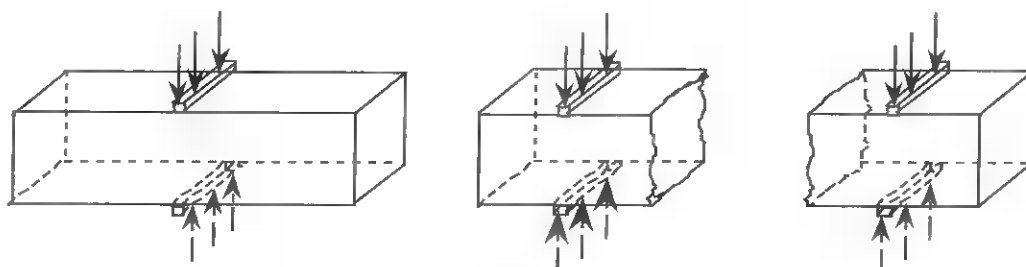

Diagram showing the principle of the tensile splitting test

4.2. Calculations

The tensile splitting strength of the blocks is expressed by the formula

$$f_b{}^t dry = 0{,}9 \times 10 \times \frac{2F}{\pi \times l \times h} \text{ or } f_b{}^t dry = 9 \times \frac{2F}{\pi \times l \times h} \text{ in which:}$$

$f_b{}^t dry$: tensile strength of the blocks in Mega Pascal (MPa), or MN/m² or N/mm²

F: maximum load supported by the two half-blocks in kilo Newtons (kN),
w: width of the block in centimetres (cm),
h: height (thickness) of the block in centimetres (cm).

The average tensile strength of the blocks is the arithmetic average of the tensile strengths of at least three tests carried out on samples from the same lot.

Compressed Earth Blocks: testing procedures

5. Reporting the results

Calculation form (see following page).

6. References

- NBN/B 24-301 *Projet de norme Belge concernant l'approche et le calcul de maçonnerie*, 1976.
- ENTPE Geomaterials laboratory: A. Mesbah, Z. El Gharbi, M. Olivier,
  Proposition d'une norme pour la réalisation d'essais de résistance sur BTC. Vaulx-en-Velin, France, September 1995.
- ENTPE Geomaterials laboratory: M. Olivier, A. Mesbah, Z. El Gharbi, JC. Morel;
  Mode opératoire pour la réalisation d'essais de résistance sur blocs de terre comprimée. Matériaux et construction, vol. 30, November 1997, pp. 515-517.

TEST RESULTS FORM : DRY TENSILE STRENGTH

SAMPLE :	*Red blocks*	ORIGIN : *XY*
OPERATOR :	*NN*	LABORATORY : *YZ*
DATE :	*21/06/00*	

	BLOCK 1	BLOCK 2	BLOCK 3
AGE OF BLOCKS	*3 weeks*	*3 weeks*	*3 weeks*

DIMENSIONS AND ▇▇▇▇ OF SAMPLES	BLOCK 1	BLOCK 2	BLOCK 3
Length (L) in cm	*29.5*	*29.5*	*29.5*
Width (w) in cm	*14*	*13.9*	*13.8*
Height (h) in cm	*9*	*8.9*	*9.2*
Volume (V) in cm³	*3717*	*3649.5*	*3745.3*
Dry mass of blocks (m_d) in g	*6661*	*6507*	*6685*
Dry density (kg/m³) $\rho_d = \dfrac{1000 \times m}{V}$	*1792*	*1783*	*1785*

TYPE OF LOAD	*Constant displacement*		*0.02 mm/seconds*

CRUSHING	BLOCK 1	BLOCK 2	BLOCK 3
Crushing time	*2.2 seconds*	*1.95 seconds*	*2.1 seconds*
Breaking load (F) en kN	*7.4 kN*	*7.6 kN*	*7.4 kN*
Dry tensile strength of the blocks $f_b{}^t dry = 9 \times \dfrac{2F}{\pi \times l \times h}$ in MPa	*0.336 MPa*	*0.352 MPa*	*0.334 MPa*
Average dry tensile strength of the blocks ($f_b{}^t$ dry)	*0.34 MPa*		

PARTICULAR CURING CONDITIONS

The blocks come straight from the production unit where they have been stored for 7 days under plastic and for 2 weeks in the open.

Compressed Earth Blocks: testing procedures

Abrasive strength test

Compressed earth blocks : testing procedures
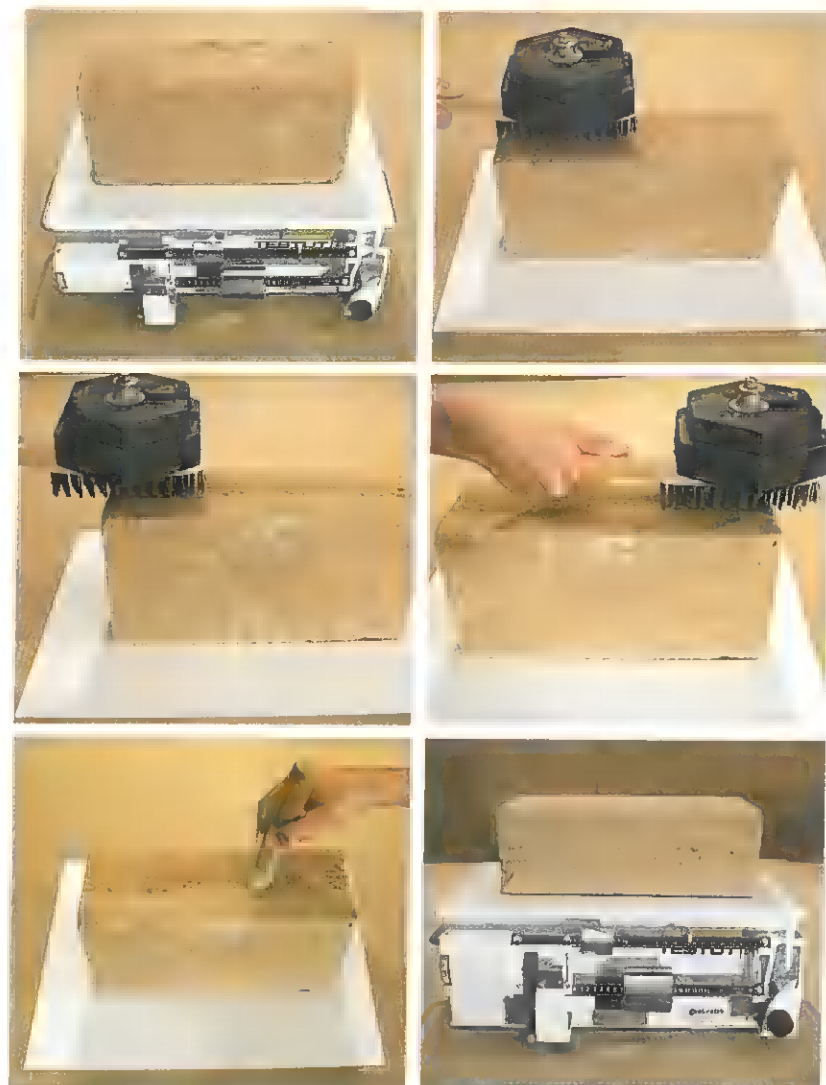
1. General

1.1. Object of the test

To determine the abrasive strength of CEBs used in facing masonry. This value is not directly linked to mechanical strengths, but is generally closely linked to the nature of soils and to the rates of stabilisation of the material.

1.2. Principle of the test

A CEB is subjected to mechanical erosion applied by brushing with a metal brush at a constant pressure over ■ given number of cycles.
The brushing is applied to the sides of the block which are actually used as facing, i.e. usually the header or the stretcher.
The abrasion coefficient can then be calculated; this expresses the ratio of the surface to the quantity of the material removed by brushing and is proportional to the abrasive strength.

Standards ARS 674, 675, 676, 677 give the abrasive strength values in percentage mass (mass of lost matter / mass of the block before abrasion), this value being one of the standardised classifications for CEBs to be taken into account. However, the abrasion coefficient gives ■ more significant value which is also easier to compare, regardless of the configuration of the CEBs.
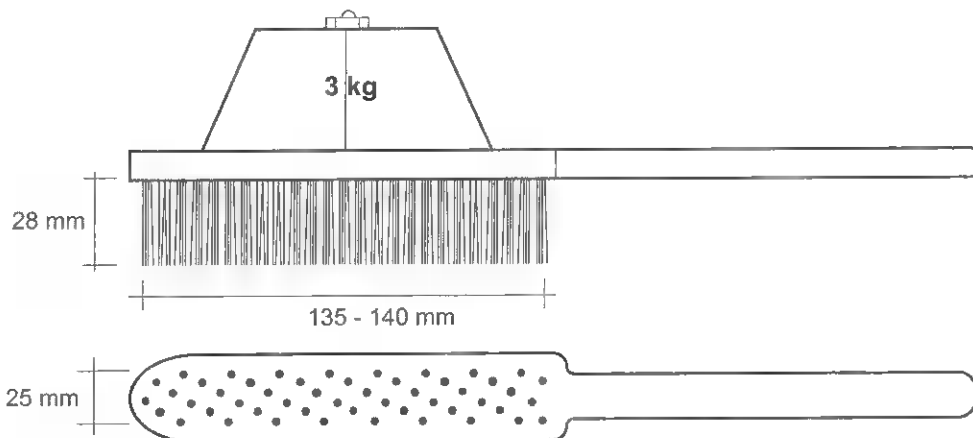
2. Apparatus

2.1. Apparatus in common use

- a rule
- a balance readable to 10 kg and accurate to 1 gram. For masses > 10 kg accuracy of ± 5 g is permissible.

2.2. Special apparatus

- 1 steel wire brush, of the kind shown below and loaded with ■ mass of 3 kg.


3. Preparing the sample

The CEBs are all produced in the same way at the optimum water content of the mix of which they are made (depending on the equipment used) and from a sample of soil which is representative of the material tested.

4. Test procedure and calculations

4.1. Test procedure

- Weigh and number each block from 1 to 5 (or 6), from the lightest to the heaviest, i.e. m_1;
- Place the block on a horizontal work surface for brushing; the brush shall be laid on the block (so that its mass is vertically applied to the latter).
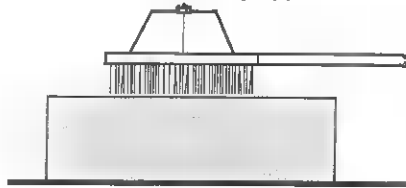
- The facing side of the block (depending on how it is to be used) should be brushed; failing this, for preference, the stretcher should be selected.
- Brush the surface of the CEB using the wire brush to the middle of which a 3 kg mass has been correctly attached. Brushing should consist in one forward and backward motion per second for one minute (i.e. 60 cycles). The operator should apply no vertical pressure to the brush when handling it. The brushed area of the CEB should not exceed the width of the brush by more than 2 mm.
- Brushing should take place along the whole length of the block and at least half the surface of the brush should remain permanently in contact with the surface of the CEB for the whole duration of the test. This is to avoid any angling of the brush which would put greater pressure on the edges of the block.
- When brushing is complete, all loose matter is removed from the CEB and weighed (m_1). The mass of detached matter, i.e. $m_1 - m_2$, is recorded.
- Calculate the brushed surface area $S = L \times w$ (in mm),
    - L : length of the brushed face of the block,
    - w : width of the brush (in principle 25 mm)

w = 25 mm ± 2 mm

L (usually 29.5 cm)
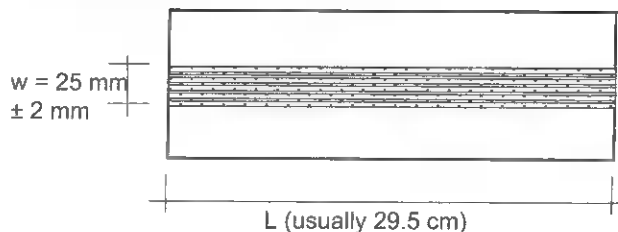
4.2. Calculations

By definition, the abrasion coefficient (C_a) expresses the ratio of the brushed surface S (in cm^2) to the mass of the material detached by the brushing ($m_1 - m_2$, in grams).

Abrasion Coefficient: C_a (cm^2/g) = $\dfrac{S}{m_1 - m_2}$

5. Reporting the results

Calculations form (see following page).

6. References

- R. Sperling, U.D.C. 691.327, Soil-cement blocks "A field test for suitable mix proportions"; September 1961; West African Building Research Institute, ACCRA, GHANA.
- Amina FADLI, *"Protection de murs en terre non stabilisée, cas des enduits en terre"*, Dissertation for post-graduate degree in building with earth, *CEAA-Terre* 1993-1994, French Ministry of Works, Transport and Tourism, Department of Architecture and of Urban planning, Grenoble, France.

TEST RESULTS FORM : ABRASIVE STRENGTH

SAMPLE :	*Red blocks*	ORIGIN : *XY*
OPERATOR :	*NN*	LABORATORY : *YZ*
DATE :	*21/06/00*	

MASSES OF BLOCKS	BLOCK 1	BLOCK 2	BLOCK 3	BLOCK 4	BLOCK 5
mass before brushing (m_1) in g	3486	7281	7300	7355	7338
mass after brushing (m_2) in g	3482.5	7275	7287	7345	7325
mass of lost matter (m_1-m_2) in g	3.5	6	13	10	8

ABRASION COEFFICIENT	BLOCK 1	BLOCK 2	BLOCK 3	BLOCK 4	BLOCK 5
$\frac{m_1-m_2}{m_1} \times 100$ in (%)	0.1 %	0.08 %	0.18 %	0.14 %	0.11 %
Length of brushing L (cm)	14	29.5	29.5	29.5	29.5
Width of brushing w (cm)	2.5	2.5	2.5	2.5	2.5
Surface area brushed (cm^2) = L x w	35	73.75	73.75	73.75	73.75
Abrasion coefficient $C_a = \frac{S}{m_1-m_2}$ (cm^2/g)	10	12.3	5.7	7.4	9.2

Illustration of relationship between loss of mass and Abrasion coefficient
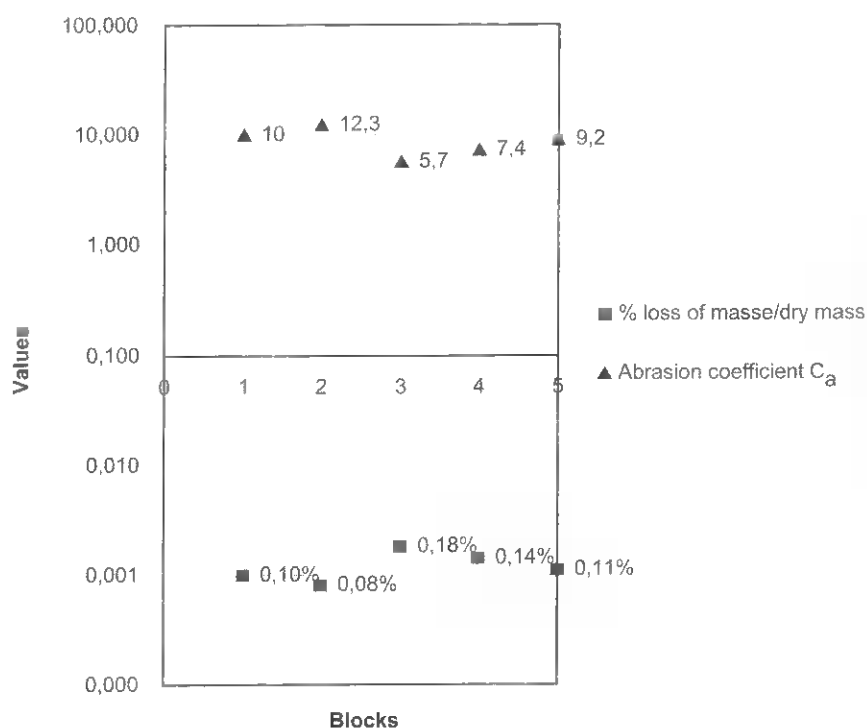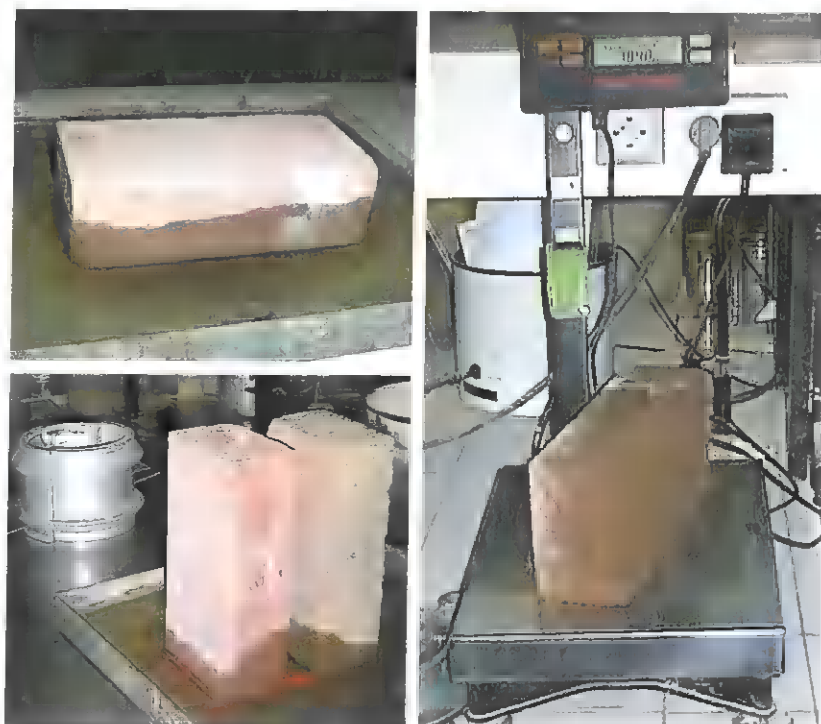
Capillary absorption test

CAPILLARY ABSORPTION

1 General

1.1. Object of the test

CEBs used in ■ structure may be subject to alternating phenomena of absorption and desorption. In most cases this is because of ■ "capillary environment" in which capillary rise occurs.

1.2. Principle of the test

In this test, the material is partially immersed to ■ height of 5 mm. Conditions must therefore be such that the block is always immersed to the same height. The absorption coefficient of water corresponds to the speed of absorption. This value is more representative of the behaviour of masonry subjected to a violent storm than its absorption capacity measured at saturation.

Standards ARS 674, 675, 676, 677 give absorption values in percentage mass (mass of water absorbed/ mass of the block before wetting), this value being one of the standardised classifications for CEBs to be taken into account. It corresponds to the absorption capacity to saturation of a block in a capillary absorption situation after several days. However, the absorption coefficient as it is given here indicates the speed of absorption of ■ block after 10 minutes. This value is more representative than what could be measured on actual CEB masonry subjected to a violent storm. The absorption coefficient measured after 10 minutes is a way of characterising a material which is already in use for other small masonry elements. It will therefore be possible to compare the specific values obtained for CEBs with those of other similar materials depending on progress in research in this field.

2. Apparatus

2.1. Special apparatus

- A tray containing drinking water;
- 4 wedges adjustable in height.

2.2. Apparatus in common use

- Ventilated drying oven capable of maintaining ■ temperature of 40°C.
- A balance readable to 10 kg and accurate to 1 gram. For masses > 10 kg accuracy to ± 5 g is permissible;
- ■ 250 ml flask for constantly maintaining the correct water level;
- a precision ruler graduated in mm;
- a stop watch;
- ■ non-absorbent cloth or chamois leather.

3. Preparing the sample

Dry the blocks in a ventilated oven-dry at 40°C until ■ constant mass is obtained. The mass of the block is constant when the difference in mass between 2 weighings at ■ 24 h interval is < 0.1% of the initial mass.

- Weigh each block to the nearest 2 g and number them.
- Place the blocks in the oven in the position in which they would be when in actual use, in such a way that the hot air can circulate over all the faces.
- Dry the blocks out until a constant mass is obtained. The mass is considered constant when the difference in mass between 2 weighings at ■ 24 h interval is < 0.1% of the initial mass.
- Leave the blocks to stabilise in the laboratory for 6 h.
- Weigh each block , thus: m_{d1}, m_{d2}, m_{dn},..., mass of the dry block (in grams).
- Measure the dimensions of the surface to be immersed in cm.

4. Test procedure and calculations

4.1. Test procedure

- Immerse ■ smooth facing side so that it is 5 mm beneath the surface of the water. The immersion should be carried out by resting the products on wedges placed at the bottom of the tray and allowing water to circulate all round the immersed face.
- Position the flask (or reservoir) filled with water so that the water level remains constant.
- After 10 min, remove the block from the water and dry it with ■ damp cloth or chamois leather.
- weigh the block, thus: m_{h1}, m_{h2}, m_{hn},..., mass of the wet block in the course of the test (in grams).
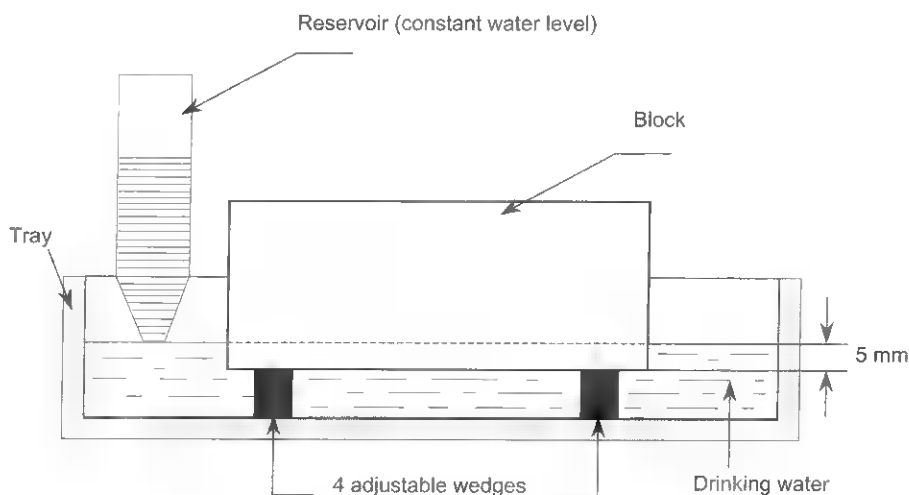
4.2. Calculations

The water absorption coefficient C_b of each block is by convention expressed by the formula:

$$C_b = \frac{100 \times (m_h - m_d)}{S\sqrt{t}} = \frac{100 \times (m_h - m_d)}{S\sqrt{10}}$$

in which:

$m_h - m_d$ is the mass of water, in grams, absorbed by the block during the test;

S   is the surface area of the submerged face, in square centimetres;

t   is the duration of time of the immersion of the block, in minutes.

5. Reporting the results

Calculations form (see following page).

Compressed Earth Blocks: testing procedures

TEST RESULTS FORM : WATER ABSORPTION BY CAPILLARITY

SAMPLE : *Red blocks*	ORIGIN : *XY*
OPERATOR : *NN*	LABORATORY : *YZ*
DATE : *21/06/00*	

Dimensions of the immersed face of the blocks

	BLOCK 1	BLOCK 2	BLOCK 3
Length (L) in cm	*24*	*24*	*24*
width (w) in cm	*12.3*	*12.2*	*12.2*
Surface area (cm^2) = L x l	*295.2*	*292.8*	*292.8*

Masses of the blocks

mass of the block in its natural state = (m) in g	*∕*	*∕*	*∕*
mass of the block after drying = (m_d) in g	*2783*	*2956*	*2875*
mass of the blocks after 10 minutes' wetting = (m_h) in g	*2831*	*3005*	*2925*
mass of the water absorbed = (m_h - m_d) in g	*48*	*49*	*50*

Water capillary attraction absorption coefficient

$C_b = \dfrac{100 \times (m_h - m_d)}{S\sqrt{10}}$	*5.142*	*5.292*	*5.400*
AVERAGE $C_b = \dfrac{C_{b1} + C_{b2} + C_{b3}}{3}$	*5.3*		
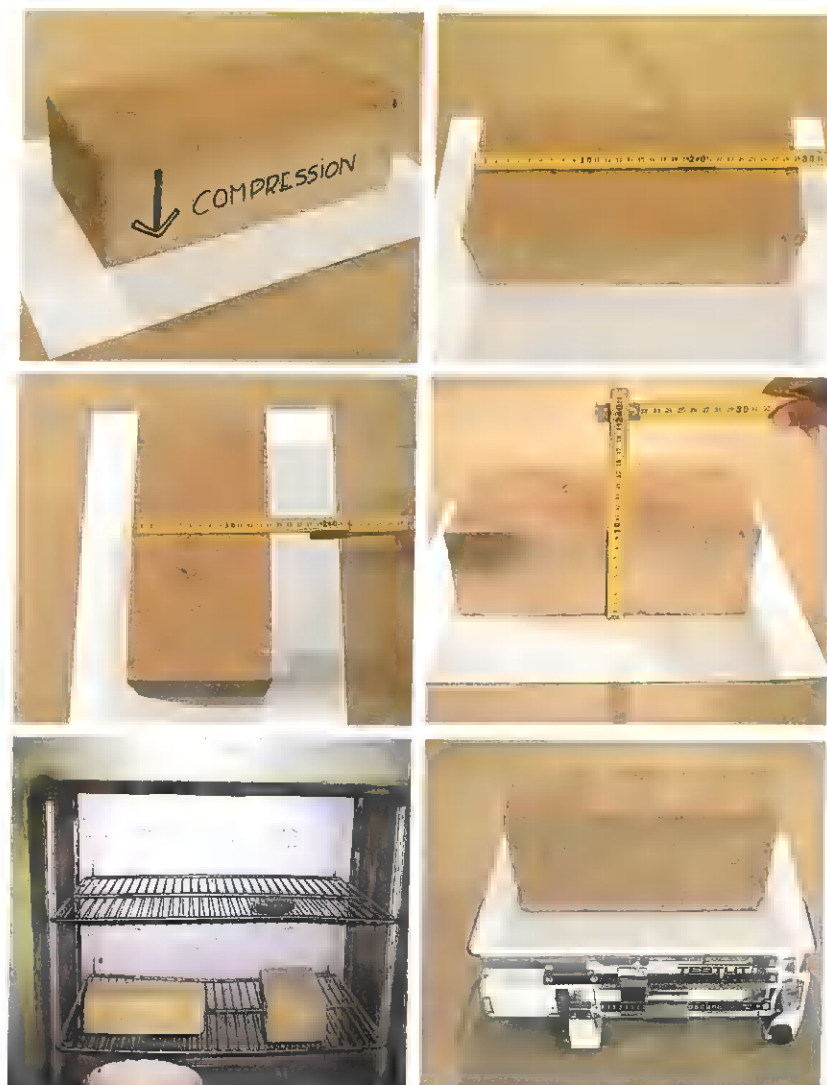
Dimensions, mass and apparent density measurement

DIMENSIONS, MASS, APPARENT DENSITY

1. General

1.1. Object of the test

To determine the physical characteristics of a block.

1.2. Principle of the test

Dimensions
The size of ■ block does not correspond exactly to the nominal dimensions of the mould box of the press. On removal of the block, a "slumping" effect occurs, followed by some shrinkage on drying.
The mould box may buckle and the press compression plates may tip.
Thus the length, width and height of the block may not be constant. Each face of the block therefore needs to be measured.

Mass
A block always contains water which is in equilibrium with the ambient environment as the material is hygroscopic. The block must therefore be weighed after oven-drying when it has attained its equilibrium and when its mass is constant.

Density
The apparent density will give us an indication of the extent of compaction of the block. This requires accurate measurements of its volume and mass.

2. Apparatus

-     Ventilated drying oven capable of maintaining ■ temperature of 105°C;
-     Precision ruler;
-     Calipers;
-     A balance readable to 10 kg and accurate to 1 gram. For masses > 10 kg accuracy to ± 5 g is permissible.
-     non-absorbent cloth or chamois leather.

### 3. Preparing the sample

-     The blocks must be at least 3 weeks old.
-     Wipe the block using ■ non-absorbent cloth in order to remove any dust or loose matter stuck to it.
-     Note the appearance of the block.

4. Test procedure and calculations

Dimensions

-     Identify the direction in which the blocks would be laid.
-     Note if this corresponds to the direction in which the blocks were compressed.
-     Define the dimensions: Length (L), width (w), height (h)
    - Length (L): the largest dimension of the block,
    - width (w): the block dimension corresponding to the width of the laying face,
    - Height (h): the dimension of the block measured in the direction of the compression or in more general terms, the smallest dimension of the block.
-     Measure to the nearest millimetre each dimension of the block in the middle of each face and calculate the averages.
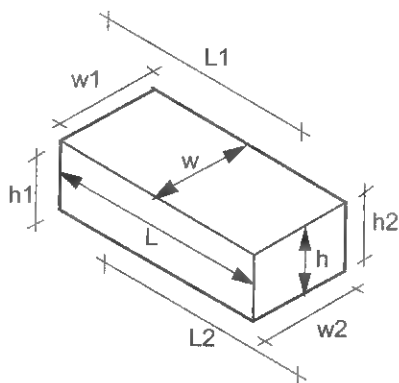
$$L = \frac{L_1 + L_2}{2}$$

$$w = \frac{w_1 + w_2}{2}$$

$$h = \frac{h_1 + h_2}{2}$$

- Calculate the volume of the block: $V = L \times w \times h$ (in cm^3).

Mass

- The block is oven-dried until a constant mass is obtained. The mass of the block is considered to be constant when the difference in mass between 2 weighings at a 24 h interval is < 0.1% of the initial mass.
- On removal from the oven the block is left open to ambient air for 2 hours.
- After this interval, weigh the block mass m (in g, to the nearest g).

Density

- The dry density is given as the ratio of the mass of the block to its volume, thus
- ρ_d (in g/cm^3) = $\rho_d = \frac{m}{V}$

5. Reporting the results

Calculations form (see following page).

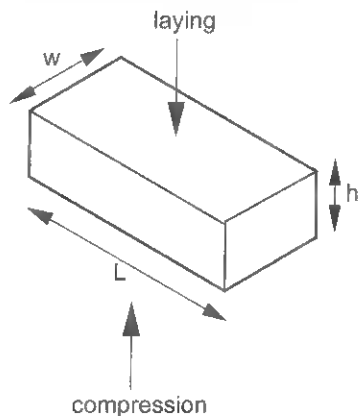| SAMPLE :	*Red blocks*	ORIGIN : *XY*
OPERATOR :	*NN*	LABORATORY : *YZ*
DATE :	*21/06/00*	

DIMENSIONS

Diagram showing:
   The direction of compression and/or of laying,
   The direction of laying L, w and h.

$L_1 = 29.6\ cm$
$L_2 = 29.5\ cm$

Length (L) in cm

$$L = \frac{L_1 + L_2}{2} = 29.55\ cm$$

$l_1 = 14.1\ cm$
$l_2 = 14.2\ cm$

Width (w) in cm

$$w = \frac{w_1 + w_2}{2} = 14.15\ cm$$

$h_1 = 9.1\ cm$
$h_2 = 9.5\ cm$

Height (h) in cm

$$h = \frac{h_1 + h_2}{2} = 9.3\ cm$$

Volume of block: $V = L \times w \times h\ (cm^3)$

$$V = 3\ 888.6\ cm^3$$

MASS

Mass of block = m (g)

$$m = 6\ 525\ g$$

APPARENT DENSITY

Apparent density of the block = $\rho_d = \dfrac{m}{V}$ (g/cm³)

$$\rho_d = 1.68\ g/cm^3$$

ANNEXES

ANNEX 1 : CALIBRATION OF HYDROMETER

Symbols used

H_r = effective depth of the centre of force.
H_o = distance separating the centre of force from graduation 1,000.
H_1 = distance from the neck of the bulb to graduation R.
h = height of the bulb.
d = distances separating 2 successive graduations.
C_t = temperature correction.
C_m = meniscus correction.
C_d = dispersing agent correction.
R = hydrometer reading (upper limit of meniscus).
R_t = reading at the lower limit of the meniscus $R' = R + C_m$
R_1 = corrected reading $R_1 = R \pm Cr + C_m - Ca$.

Before using a hydrometer for sedimentation analysis tests, the "composite correction" to be applied to readings to take account of the following must be determined:

  1 - variations in temperature during the test (correction C_t).

  2 - the meniscus (correction C_m).

  3 - the dispersing agent (correction C_d).

  The significance of the three corrections listed must be established by experimentation and the reading to be used in calculating the percentages of grains smaller than D will be:

$$R_1 = R (\pm)C_t + C_m - C_d$$

Equipment required for calibration:

1 - The hydrometer to be calibrated.
2 - Two identical 2,000 cm^3 measuring cylinders.
3 - A thermometer graduated in 1/10 degrees from + 10 to + 35 °C.
4 - A pipette graduated at 5 cm^3.
5 - De-mineralised water (distilled water). pH = approx. 6., resistivity $p = 500,000 \ cm^2/cm$.
6 - Dispersing agent: sodium hexametaphosphate in 5% solution, sold commercially in crystallised form.

A.1 - TEMPERATURE CORRECTION

Hydrometers are generally calibrated at 20°C by the manufacturer. They therefore indicate for distilled or de-mineralised water the reading 1,000 at 20°C (although this value is actually achieved by water only for a temperature of 4°C).

As temperatures during tests practically always differ from 20°C, ■ correction is necessary to take account of the density of the water at the temperature at which the test is carried out and of variations in the volume of the hydrometer bulb.

To determine the temperature correction, proceed as follows:

-   Fill two identical measuring cylinders with 2,000 cm³ of de-mineralised (or distilled) water. Using ■ refrigerator and an oven, bring one of the cylinders to 10°C and the other to + 35°C.

-   Place the two measuring cylinders side by side and take the hydrometer readings corresponding approximately to each variation in temperature from 0.3 to 0.5 degrees for each of the two cylinders, and continue to do this until the temperatures stabilise at the ambient temperature. Before taking the hydrometer and the thermometer readings, stir the water so that the temperature is the same from the top to the bottom of the cylinders and take readings R' *(at the lower limit of the meniscus)* having first allowed the hydrometer to float for a few seconds to allow it to reach the same temperature as the water.

-   Note the temperatures and the corresponding R readings.
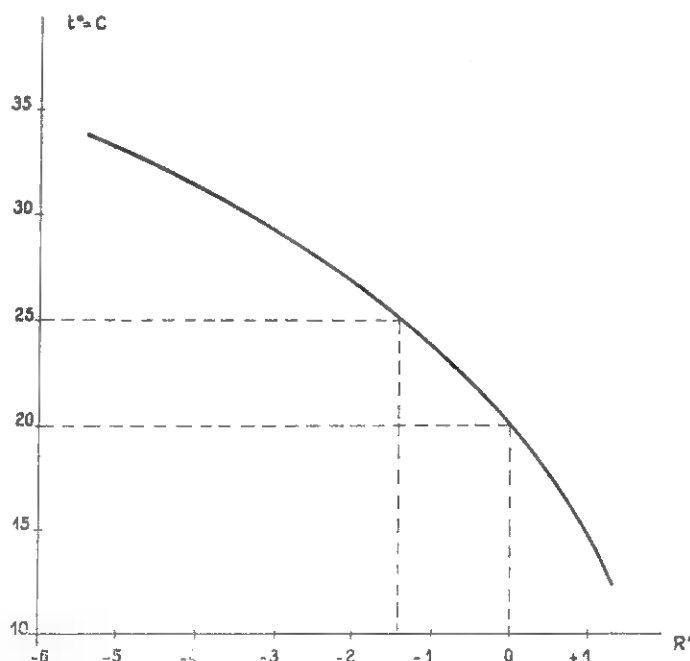
Fig. 5. – Curve of readings R' in pure water compared to temperature

Using the results, trace to draw the curve $R' = \varphi\,(t)$ (see example in *fig. 5)*. Note that R should be expressed in number of divisions of the hydrometer, using the + sign if it is greater than 1,000 and the – sign if it is lower. One therefore obtains the corrections C_t to be applied to the reading R. For example, for 25°C one takes a reading of 0.9985 i.e. –1.5. Therefore +1.5 must be added to the reading to restore initial conditions.

A.2 – MENISCUS CORRECTION

Hydrometers are generally graduated to be read at the lower limit of the meniscus which the water forms around the neck. With the opaque suspensions of sedimentation analysis tests, this is no longer possible and readings have to be taken at the upper limit of the meniscus, which means that a correction must be made to allow for the height of the latter. The significance of this correction is greater than the temperature correction.

The correction is obtained by placing the hydrometer, the neck of which will have previously been cleaned to allow the meniscus to form correctly, in de-mineralised (or distilled) water. The difference between readings R and R' taken respectively at the upper and at the lower limit of the meniscus gives the correction C_m. This correction must be added to the reading R.

A.3 – DISPERSING AGENT CORRECTION

The addition of a dispersing agent modifies the reading taken in the de-mineralised water. The extent of the correction to be applied to the reading R can be determined in the following manner:

- fill a measuring cylinder with 2,000 cm³ of de-mineralised water and take a reading at the upper limit of the meniscus. Add the quantity of dispersing agent stated in the operational procedure, stir the liquid well to ensure it is evenly distributed, and take another reading at the upper limit of the meniscus. The difference between the two readings is the correction C_d to be applied to the reading R.

The final correct reading is therefore
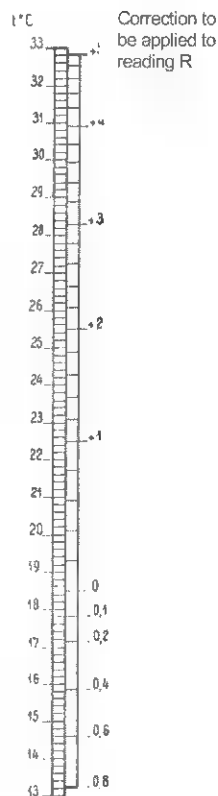
$$R_1 = R \pm (C_t) + C_m - C_d$$

Fig. 6. – Scale of corrections to take account of the temperature, the meniscus and the dispersing agent.

For the common tests in the course of which one adopts ■ grain density of 2.65 g/cm^3, it is useful to draw up ■ chart taking account of all three corrections at once. To do this, add the height of the meniscus to the temperature corrections, and subtract the dispersing agent correction.

Based on *fig. 5*, *fig. 6* on the previous page gives an example of this kind of correction chart for ■ height of meniscus of +0.4 and a correction of −0.8 for the presence of sodium hexametaphosphate.

Note: It is useful to seek the corrections C_t and C_d simultaneously by establishing the curve $R = \varphi$ (t) for the de-mineralised water plus dispersing agent mixture.

A.4- ESTABLISHING THE CHARACTERISTIC VALUES (*Ho*, *Hr*) OF A HYDROMETER

When one wishes to calculate equivalent diameters with precision in the light of density, it is necessary to determine the effective depth H, of the centre of the load at the time of the readings.

As hydrometer manufacturers cannot accurately respect the dimensions indicated in the operational procedure, these have to be researched in the laboratory for each hydrometer. To do this, determine:

1 - The volume V of the hydrometer: there are three possible procedures for doing this:

  - introducing the hydrometer into a measuring cylinder and recording the increase in volume.
  - calculating the volume.
  - weighing the hydrometer to the nearest 0.001 g, since its mass in grams is approximately equal to its volume in cubic centimetres. The error due to the stem being immersed to a greater or lesser extent during the sedimentation analysis tests is negligible.

2 - The section A of the measuring cylinder either by calculation, or by finding the distance between two graduations (for example 500 and 2,000 cm^3) and by dividing the volume contained between the two graduations by this distance.

3 - The distances between the last graduation of the hydrometer and each of the other main graduations (1,020, 1,010, 1,000).

4 - The distance between the last graduation and the neck of the bulb h_4,

5 - The height of the bulb h.

6 - The distance between the neck of the stem and the graduation read as R i.e. H_1.

These distances can be determined using calipers.

The effective depth H_r of the centre of the force is then calculated (*fig. 7*) using the formula:

$$H_r = H_1 + \frac{1}{2}\left(h - \frac{V}{A}\right)$$

i.e. corrected effective depth = distance between the neck of the stem and the reading

$$R + \frac{1}{2}\left[\text{length of bulb} \quad - \quad \frac{\text{volume of bulb}}{\text{section of cylinder}}\right]$$

This formula applies to all readings except the first three, i.e. at 0.5, 1 and 2 minutes, during which the hydrometer is held in the suspension.

In fact the above formula takes account of the increase in the level of the suspension in the measuring cylinder when the hydrometer is introduced. This is necessary since for readings after 2 minutes the hydrometer is introduced just before the reading and withdrawn immediately after. Thus,
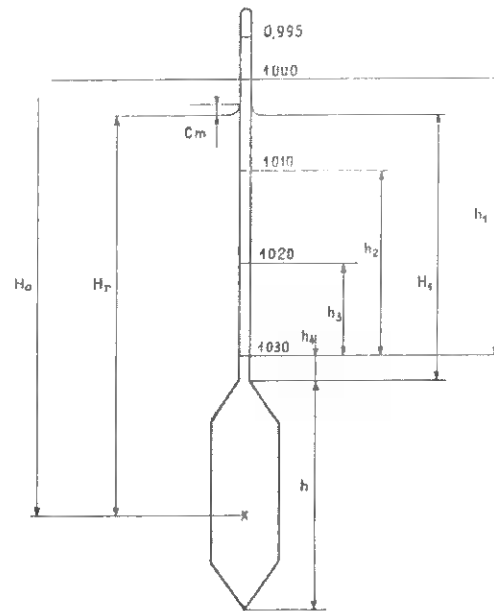
Fig. 7.
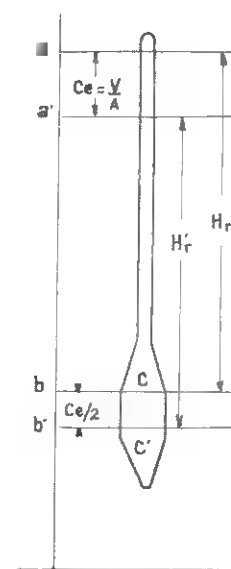
Fig. 8.

since inserting the hydrometer of immersed volume V results in an increase in the level of the suspension in the measuring cylinder of section A by the quantity V/A, the particles settle from the height $a' b' = H'r$ while one measures $ab = Hr$.

However, by eliminating the volume of the stem of the hydrometer, the centre of the load is approximately the geometric centre of the bulb (fig. 8). Therefore if the entire volume of the bulb has displaced the level of $Ce = V/A$, half the bulb (at the level of the centre of the load) has displaced the suspension of $1/2\ Ce = 1/2\ V/A$, an expression which we also find in the formula above.

For the first three readings, the hydrometer remains in the suspension and the particles settle from the distance $Hr = ab$ which is actually measured. In this case consequently, the depth of the centre of the load is $Hr = H_1 + 1/2\ h$.

In order to be able to calculate the effective depth easily and at any moment, it is convenient to use the formula $Hr = Ho - R'\ d = Ho - (R + Cm)\ d$, where Ho is determined once and for all for a hydrometer and a measuring cylinder.

R' being the reading of the hydrometer (reading at the upper limit of the meniscus plus meniscus correction), i.e. $R' = R + Cm$.
d being the distance separating two consecutive graduations.

$H_o =. H_r$ for the reading 1,000 i.e.

$H_o = H_r + 1/2 (h - V/A)$

For the hydrometer shown on page 28, this gives:

$H_o = 13.0 + 1/2 (18.4 - 73/57)$

i.e. $H_o = 21.6$ for readings after the first 2 minutes,

and $H_o. = 13 + 1/2 \; 18.4 = 22.2$ for the three first readings, hence the table of effective depths below for the hydrometer in question given $d = 0.38$ cm.

Reading $R' = R + C_m$	(For the first three readings)	Effective depth H_r
0	22.2	21.6
1	21.8	21.2
2	21.4	20.8
3	21.0	20.4
4	20.7	20.0
5	20.3	19.7
6	19.9	19.3
7	19.5	18.9
8	19.2	18.5
9	18.8	18.1
10	18.4	17.8
il	18.0	17.4
12	17.6	17.0
13	17.3	16.6
14	16.9	16.2
15	16.5	15.9
16	16.1	15.5
17	15.7	15.1
18	15.4	14.7
19	15.0	14.3
20	14.6	14.0
21	14.2	13.6
22	13.8	13.2
23	13.5	12.8
24	13.1	12.4
25	12.7	12.1
26	12.3	11.7
27	11.9	11.3
28	11.6	10.9
29	11.2	10.5
30	10.8	10.2

The table above used in conjunction with the calculator graph *fig. 9* enables one to quickly calculate equivalent diameters.
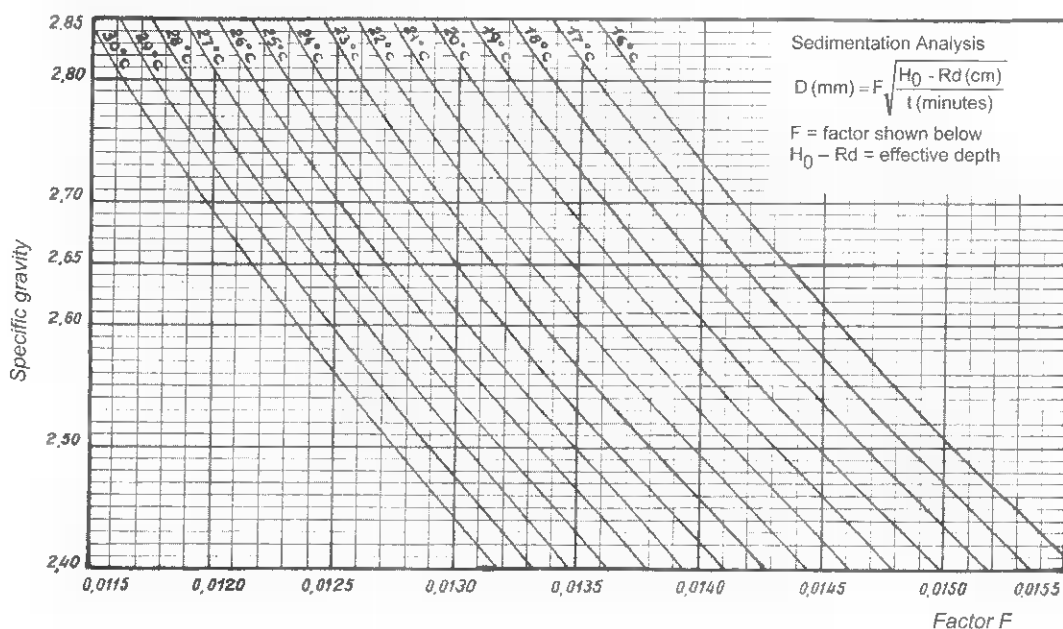

Fig. 9

Compressed Earth Blocks: testing procedures

ANNEX 2: TEST EQUIPMENT

1. Apparatus in common use

-   Ventilated drying oven capable of maintaining a temperature of 105°C.
-   Oven reaching a temperature of 400°C.
-   A hotplate or alternatively ■ micro-wave oven.
-   A hair dryer.
-   A balance readable to 200 g and accurate to 1/100 gram.
-   A balance readable to 600 g and accurate to 1/10 gram.
-   A balance readable to 10 g and accurate to 1 gram. For masses > 10 kg accuracy of ± 5 g is permissible.
-   Evaporating dishes capable of withstanding the temperature of the drying oven.
-   At least 4 to 5 trays measuring 40 x 30 x 6 cm (alternatively 30 x 22 x 5 cm).
-   A pair of insulated gloves.
-   A square plastic tray with 150 mm long sides 60 mm high.
-   500 ml flexible plastic wash bottles.
-   A 100 ml or 50 ml capacity burette graduated to 1/10 ml or 1/5 ml or one 5 ml and one 2 ml micro-pipette.
-   A 250 ml flask.
-   A 3l plastic flask with ■ diameter of 155 mm.
-   A scoop.
-   Spatulas and spoons.
-   A sieve brush with nylon hairs.
-   2 litre measuring cylinders (at least 2): inner diameter 85 mm, height of graduations 450 mm or 1 litre measuring cylinders: inner diameter 60 mm.
-   A manual stirrer, compatible with the inner diameter of the measuring cylinders listed above.
-   A stirrer with paddles, turning at between 400 and 700 r.p.m., the diameter of the paddles being in the range 70 mm to 80 mm.
-   A mechanical stirrer the rotation speed of which can be adjusted from 0 to 10,000 r.p.m. This stirrer should be of the "plunger" type, i.e. the spindle of the rotating pallet is inserted into the receptacle containing the solution; this receptacle should not have smooth sided cylindrical walls.
-   A thermometer graduated to 1/10 of a degree from approximately + 10 à + 35°C.
-   A glass rod: length 300 mm; diameter: 8 mm.
-   A stop watch showing seconds.
-   A mortar approximately 20 cm in diameter with a rubber pestle.
-   A glass, marble or Plexiglas plate or slab measuring approximately 250 x 250 x 6 mm.
-   A short-handled brush.
-   Liquid paraffin.
-   A precision ruler graduated in mm.
-   A mallet and knife or blade to make half-blocks.
-   A one metre rule.
-   Calipers.
-   A non-absorbent cloth or ■ chamois leather.

■. Special apparatus

-   A minimal series of ø 200 mm sieves with square meshes measuring as follows: 20/10/5/2/1/0.4/0.2/0,1 and 0.08 mm.
-   A long stem hydrometer (Bouyoucos type) graduated from 0.995 to 1,030 g/cm^3 with graduations every 0.0005 g/cm^3.
-   A Casagrande apparatus with one smooth and one roughened dish; a 10 mm wedge to regulate the height of fall of the dish and ■ grooving tool which should make a 2 mm wide groove at the bottom of the dish.
-   Filter paper: quantitative and ash content < 0.01%; mass 95 g/m^2; thickness: 0.20 mm; filtration speed 75; retention diameter: 8 mm.
-   A metal brush loaded with a 3 kg mass.
-   A surface tray approximately $1m^2$ and 40 cm deep.
-   Four height adjustable wedges.

- A crushing press the speed of displacement of the plates of which can be adjusted and of ■ power compatible with the strength of the blocks. The minimal capacity of the presses is defined on the basis of the following data:
  - the press should allow compression at a pressure of between 1MPa and 20 MPa for a 200 cm^2 section.
  - The rhythm of the press should enable the set displacement to be adjusted by 0.02 mm/sec.
  - The press should allow an adjustment to the increase in loads of between 0.15 and 0.25 MPa/sec.
- 0/3 mm sand, high alumina melted cement (CA) and Portland cement (CPA-CEM I); alternatively two sheets of smooth cardboard or plywood, 3 or 4 mm thick.
- Two rigid plastic or hard wood rods with ■ section 1 x 1 cm and slightly longer than the width of the block or the specimen to be tested.
- A compressed earth block production press together with:
  - ■ wheelbarrow
  - a shovel
  - buckets of water

3. Products

- A litre of dispersing agent: sodium hexametaphosphate. $(NaPo_3)_6$
- De-mineralised water or distilled water.
- Medicinal quality methylene blue solution at 10 g/l ± 0.1 g/l. The maximum time for using the solution is 1 month and it should be stored away from sources of light and heat.

Compressed Earth Blocks: testing procedures

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TEST RESULTS FORM: WATER CONTENT

SAMPLE:	ORIGIN:
OPERATOR:	LABORATORY:
DATE:	

Determination of the mass of the test sample

- mass of test sample (m):
- size of largest elements contained in the soil

$D =$

<div style="display:flex">

$\underline{D < 0.4\ mm\ ?}$
↓
$m \geq 10\ D$
⇓

$m =$

$\underline{D \geq 0.4\ mm\ ?}$
↓
$m > 200\ g\ and = m \geq 200\ D$
⇓

$m =$

</div>

Determination of the water content

number of the evaporating dish	
mass of the evaporating dish = $m_t\ (g)$	
mass evaporating dish + wet sample = $m_{th}\ (g)$	
mass evaporating dish + dry sample = $m_{td}\ (g)$	
mass of water in the sample = $m_w\ (g) = m_{th} - m_{td}$	
mass of solid dry grains = $m_d\ (g) = m_{td} - m_t$	
water content = $W(\%) = \dfrac{m_w \times 100}{m_d}$	

TEST RESULTS FORM: PARTICLE SIZE DISTRIBUTION ANALYSIS

SAMPLE: OPERATOR: DATE:	ORIGIN: LABORATORY:

FINAL SIEVE SELECTED: | 0.1 mm | or | 0.08 mm |

MEASUREMENT OF MASS AND OF WATER CONTENT

First sample for preliminary sieving of fines

WET MASS OF THE SAMPLE m_h (g)	
DRY MASS OF THE SAMPLE: - either drying then m_d (g) - or using the measurement of the water content of the 2nd sample $m_d = \dfrac{m_{1d}}{m_{1h}} \times m_h$	

Second sample without preliminary sieving of fines

WET MASS OF THE SAMPLE: m_{1h} (g)	
MASS DRY OF THE SAMPLE m_{1d} (g)	

Cross-check: $200D < m_d < 600\,D$?   YES ❑
                                        NO ❑

SIEVING THE SAMPLES

TOTAL DRY MASS OF RETAINED FRACTION: R (g)	

SIEVE IN MM	MASS OF CUMULATED RETAINED FRACTIONS (R_i) in grams	% CUMULATED RETAINED FRACTIONS $\left(\dfrac{R_i}{m_d} \times 100\right)$	% CUMULATED PASSING FRACTIONS $\left(100 - \left(\dfrac{R_i}{m_d} \times 100\right)\right)$
20			
10			
5			
2			
1			
0.4			
0.2			
0.1			
0.08			
FRACTION PASSING FINAL SIEVE (T_n) (g)			
CUMULATED RETAINED FRACTION OF FINAL SIEVE (R_n)			
TOTAL MASS AFTER SIEVING: $R_n + T_n$			
EVALUATION OF LOSSES: $100 \times \dfrac{m_d - (R_n + T_n)}{m_d} = $ < 2 % ? YES ❑ NO ❑			

TEST RESULTS FORM: PARTICLE SIZE DISTRIBUTION ANALYSIS

SAMPLE:	ORIGIN:
OPERATOR:	LABORATORY:
DATE:	

PARTICLE SIZE DISTRIBUTION ANALYSIS

BY SIEVING — BY SEDIMENTATION

STONES | GRAVEL | COARSE SAND | FINE SAND | SILTS | CLAYS

SIEVE DIAMETER (in mm)

EQUIVALENT DIAMETER (in mm)

% OF PASSING FRACTION

TEST RESULTS FORM: SEDIMENTATION ANALYSIS

SAMPLE:	ORIGIN:
OPERATOR:	LABORATORY:
DATE:	

MAXIMUM PARTICLE DIMENSION   D =

MASS OF THE SAMPLE   m =

MEASURING CYLINDER USED   1 litre ❑   2 litre ❑

DISPERSING AGENT = ...

METHOD FOR DETERMINING THE CORRECTION FACTORS:
- CALIBRATION   ❑
- CONTROL MEASURING CYLINDER   ❑

CUMULATED RETAINED FRACTION OF TOTAL SAMPLE ON 0.1 mm OR 0.08 mm SIEVE (see D)   R =

PASSING FRACTION OF TOTAL SAMPLE ON 0.1 mm OR 0.08 mm SIEVE (see D)   T =

START TIME OF THE FINAL MIX: ....

START TIME OF SEDIMENTATION ANALYSIS: ....

| TIME	Equivalent diameter in µm	TIME min	TEMP. °C	R (readings)	C (corrected readings)	R_1 (R + C)	$p = 4R_1$ (1)	T x p (2)
	70	0.5						
	50	1						
	35	2						
	25	5						
	18	10						
	12	20						
	9	40						
	6	80						
	3.5	240						
	1.5	1440						

(1) % passing fraction of particles of the sample smaller than 0.1 or 0.08 mm
(2) % passing fraction of particles of the total sample

TEST RESULTS FORM: SEDIMENTATION ANALYSIS

SAMPLE:	ORIGIN:
OPERATOR:	LABORATORY:
DATE:	

SEDIMENTATION ANALYSIS
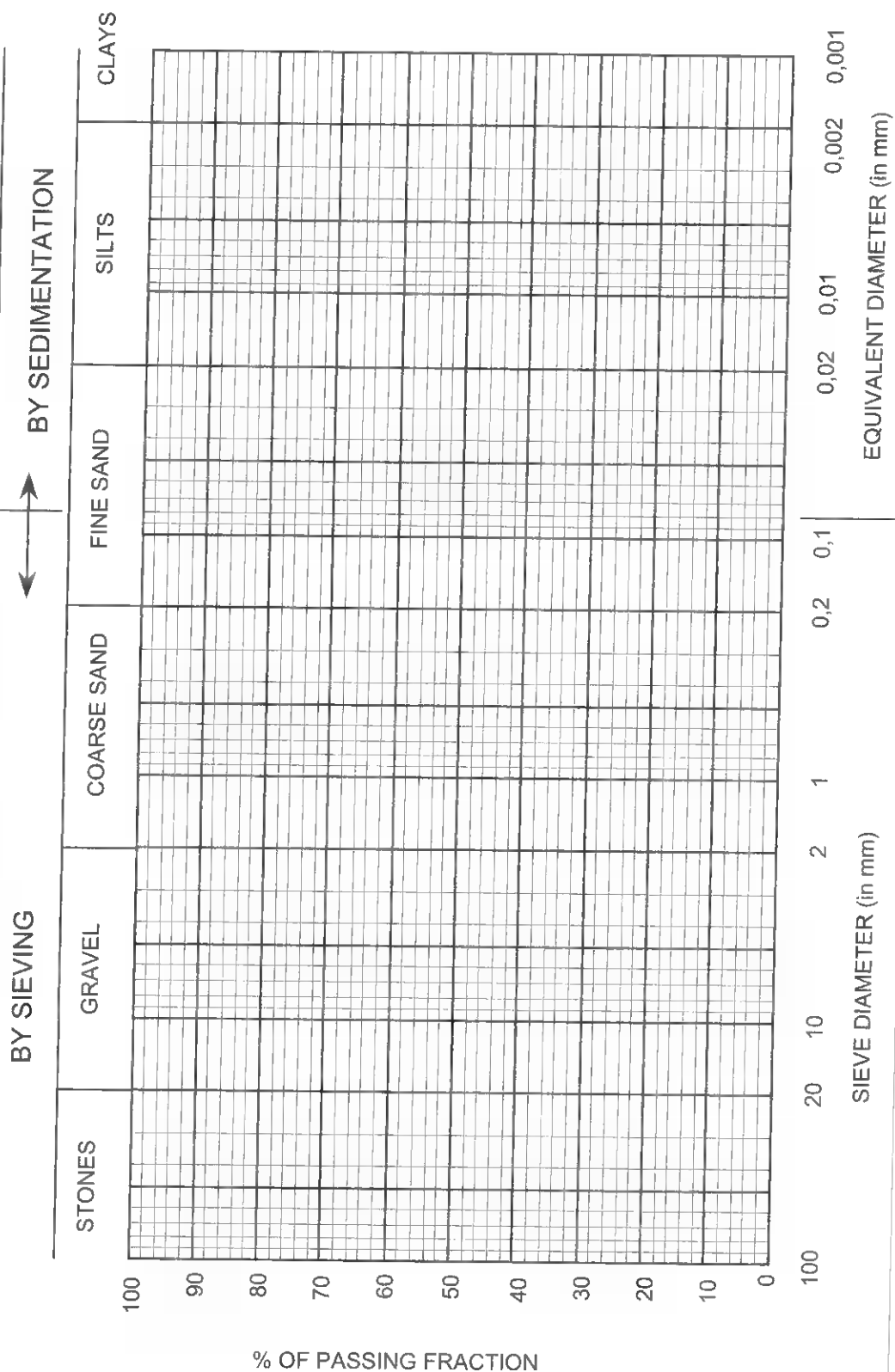
TEST RESULTS FORM: LIQUID LIMIT

SAMPLE:

OPERATOR:

DATE:

ORIGIN:

LABORATORY:

	1st test (Wl_1)	2nd test (Wl_2)	3rd test (Wl_3)
number of blows (N) $15 < N < 35$			
number of the tare (dish)			
total wet mass = m_{th}			
total dry mass = m_{td}			
tare mass = m_t			
mass of water = $m_{th} - m_{td} = m_w$			
mass of dry soil = $m_d = m_{td} - m_t$			
water content in % $\dfrac{m_w \times 100}{m_d} = W$			
$W_l = W \times \left(\dfrac{N}{25}\right)^{0.121}$ calculate or read off on calculator graph			
Average LIQUID LIMIT $W_l = \dfrac{W_{l1} + W_{l2} + W_{l3}}{3} =$			

Compressed earth blocks : testing procedures

TEST RESULTS FORM: LIQUID LIMIT

SAMPLE:	ORIGIN:
OPERATOR:	LABORATORY:
DATE:	

CALCULATOR GRAPH FOR OBTAINING THE LIQUID LIMIT

$$W_l = W \times \left(\frac{N}{25}\right)^{0.121}$$

Water content

W

Wl

Number of blows: N

TEST RESULTS FORM: PLASTIC LIMIT

SAMPLE:	ORIGIN:
OPERATOR:	LABORATORY:
DATE:	

PLASTIC LIMIT

	1st test (W_{p1})	2nd test (W_{p2})	3rd test (W_{p3})
number of the tare (dish)			
total wet mass = m_{th}			
total dry mass = m_{td}			
mass of the tare = m_t			
mass of the water = $m_{th} - m_{td} = m_w$			
mass of the dry soil = $m_{td} - m_t = m_d$			
water content in % $W = \dfrac{m_w \times 100}{m_d} =$			
Average PLASTIC LIMIT $W_p = \dfrac{W_{p1} + W_{p2} + W_{p3}}{3} =$			

PLASTICITY INDEX

$$I_p = W_I - W_p = \text{..}$$

Other important results

- % of particles smaller than 0.4 mm in the total sample = ...

- % of particles smaller than 0.002 mm in the total sample = ...

- % of particles < 0.002 mm in the < 0.4 mm sample = ...

TEST RESULTS FORM: METHYLENE BLUE

SAMPLE:	ORIGIN:
OPERATOR:	LABORATORY:
DATE:	

RELEVANT FRACTION: 0/d (mm)
where d = maximum diameter of particles in mm =

$d =$

MASS OF THE DRY SAMPLE: m_d (g)

$m_d =$

| | Injection 5 cm^3 | Injection 2 cm^3 | OUTER RING TEST | | | | |
| | | | blue outer ring: +: YES   –: NO | | | | |
			1 min	2 min	3 min	4 min	5 min
1							
2							
3							
4							
5							
6							
7							
8							
9							
total injections							
total in cm^3							
total injection in cm^3	= V_L						

METHYLENE BLUE VALUE FOR THE RELEVANT FRACTION

$MB (0/d) = \dfrac{V_L}{m_d} \Rightarrow$ ....

$MB (0/\quad) =$

SPECIFIC TOTAL AREA FOR THE RELEVANT FRACTION

$SST (0/d) = 21\ MB (0/d)$

$ST (0/\quad) =$

SUMMARY OF OTHER SIGNIFICANT VALUES:

% of the relevant fraction (0/d) for total sample
(see particle size analysis by wet sieving test (T) =

$T =$

% of particles smaller than 2 µm in the total sample (X) =

$X =$

% of particles smaller than 2 µm in the relevant fraction
$A = \dfrac{X}{T}$

$A =$

Total specific area of particles smaller than 2 µm (SSTF) =
$SSTF = \dfrac{SST (0/d)}{A} \left[\dfrac{m^2 \cdot g^{-1}}{\%} \right]$

$SSTF(0/\quad) =$

methylene blue value of the total soil (or 0/D fraction) =
MBS or MB(0/D) = MB(0/d) x T =

$MBS =$

Total specific area of the total soil =
$SST_{total\ soil}$ = 21 MBS or MB(0/D) =

$SST_{ts} =$

TEST RESULTS FORM: ORGANIC MATTER CONTENT

SAMPLE:	ORIGIN:
OPERATOR:	LABORATORY:
DATE:	

Determination of the mass of the test sample

- mass of test sample: m
- size of largest elements contained in the soil

$D =$

<center>

D < 0.4 mm ?	D ≥ 0.4 mm ?
↓	↓
$m \geq 10\ D$	$m > 20$ g and $= m \geq 200\ D$
⇓	⇓
$m =$	$m =$

</center>

Determination of the organic matter content

number of the evaporating dish	
evaporating dish mass = m_t (g)	
evaporating dish mass + dry sample = m_{td} (g)	
evaporating dish mass + sample heated to 400°C = m_{tc} (g)	
mass of solid dry grains = m_d (g) $= m_{td} - m_t$	
mass of organic matter = m_o (g) $= m_{td} - m_{tc}$	
organic matter content = $T_o(\%) = \dfrac{m_o \times 100}{m_d}$	

Cross-check: T_o < 2% ?   YES ☐
                             NO ☐

TEST RESULTS FORM: OPTIMUM WATER CONTENT

SAMPLE:	ORIGIN:
OPERATOR:	LABORATORY:
DATE:	

	BLOCK 1	BLOCK 2	BLOCK 3	BLOCK 4	BLOCK 5	BLOCK 6
Max. compactable mass of the block m_h (kg)						
Estimated water content (%)						
Calculated water content W (%)						
Length L (m)						
Width w (m)						
Height h (m)						
Volume V (m^3)						
Dry density (kg/m^3) $\rho_d = \dfrac{100 \times m_h}{V \times (100 + W)}$						

Graph of optimum water content at compaction

Dry density (kg/m3)

Note: the units are to be recorded in the light of the results

TEST RESULTS FORM: DRY or WET COMPRESSIVE STRENGTH

SAMPLE:	ORIGIN:
OPERATOR:	LABORATORY:
DATE:	

TYPE OF TEST: dry strength   ❏
                wet strength   ❏

	TEST STRUCTURE 1	TEST STRUCTURE 2	TEST STRUCTURE 3
AGE OF THE BLOCKS			

DIMENSIONS OF TEST STRUCTURES	TEST STRUCTURE 1		TEST STRUCTURE 2		TEST STRUCTURE 3	
	Lower dimensions	Upper dimensions	Lower dimensions	Upper dimensions	Lower dimensions	Upper dimensions
Length (L) in cm						
width (w) in cm						
Surface (L x w) in cm^2						
Average surface (S) in cm^2						

TYPE OF LOAD		mm/dry.

CRUSHING	TEST STRUCTURE 1	TEST STRUCTURE 2	TEST STRUCTURE 3
Crushing time			
Breaking load (F) in kN			
Compressive strength (dry or wet) of the blocks $f_b \text{ dry / wet} = 10 \times \dfrac{F\,(kN)}{S\,(cm^2)}$			
Average dry compressive strength of the blocks f_b dry			
Average wet compressive strength of the blocks f_b wet			

PARTICULAR CURING CONDITIONS

TEST RESULTS FORM: DRY TENSILE STRENGTH

SAMPLE:	ORIGIN:
OPERATOR:	LABORATORY:
DATE:	

	BLOCK 1	BLOCK 2	BLOCK 3
AGE OF BLOCKS			

DIMENSIONS AND MASS OF SPECIMENS	BLOCK 1	BLOCK 2	BLOCK 3
Length (L) in cm			
width (w) in cm			
Height (h) in cm			
Volume (V) in cm^3			
Dry mass of blocks (m_d) in g			
Dry density (kg/m^3) $\rho_d = \dfrac{1000 \times m}{V}$			

TYPE OF LOAD		mm/dry

CRUSHING	BLOCK 1	BLOCK 2	BLOCK 3
Crushing time			
Breaking load (F) in kN			
Dry tensile strength of the blocks $f_b{}^t dry = 9 \times \dfrac{2F}{\pi \times l \times h}$ in MPa			
Average dry tensile strength of the blocks ($f_b{}^t$ dry)			

PARTICULAR CURING CONDITIONS

TEST RESULTS FORM: ABRASIVE STRENGTH

SAMPLE:	ORIGIN:
OPERATOR:	LABORATORY:
DATE:	

MASS OF BLOCKS	BLOCK 1	BLOCK 2	BLOCK 3	BLOCK 4	BLOCK 5
mass before brushing (m_1) in g					
mass after brushing (m_2) in g					
mass of lost matter (m_1-m_2) in g					

ABRASION COEFFICIENT	BLOCK 1	BLOCK 2	BLOCK 3	BLOCK 4	BLOCK 5
$\dfrac{m_1-m_2}{m_1} \times 100$ in (%)					
Brushed surface length L (cm)					
Brushed surface width w (cm)					
Brushed surface area (cm^2) = L x w					
Abrasion coefficient $C_a = \dfrac{S}{m_1-m_2}$ (cm^2/g)					

COMMENTS:

TEST RESULTS FORM: CAPILLARY WATER ABSORPTION

SAMPLE:	ORIGIN:
OPERATOR:	LABORATORY:
DATE:	

Dimensions of the immersed face of the blocks

	BLOCK 1	BLOCK 2	BLOCK 3
Length (L) in cm			
width (w) in cm			
Surface (cm^2) = L x w			

Mass of the blocks

	BLOCK 1	BLOCK 2	BLOCK 3
mass of the block in its natural state = (m) in g			
mass of the dry block = (m_d) in g			
mass of the wet block after 10 minutes = (m_h) in g			
mass of absorbed water = (m_h - m_d) in g			

Water capillary attraction absorption coefficient

	BLOCK 1	BLOCK 2	BLOCK 3
$C_b = \dfrac{100 \times (m_h - m_d)}{S\sqrt{10}}$			
AVERAGE $C_b = \dfrac{C_{b1} + C_{b2} + C_{b3}}{3}$			

COMMENTS:

TEST RESULTS FORM: DIMENSIONS, MASS AND DRY DENSITY

SAMPLE :	ORIGIN :
OPERATOR :	LABORATORY :
DATE :	

DIMENSIONS

Diagram showing:
    Direction of compression and/or of laying,
    Direction of laying L, w and h.

Length (L) in cm

$L_1 = $ ....

$L_2 = $ ....

$$L = \frac{L_1 + L_2}{2} =$$

Width (l) in cm

$w_1 = $ ....

$w_2 = $ ....

$$w = \frac{w_1 + w_2}{2} =$$

Height (h) en cm

$h_1 = $...

$h_2 = $ ....
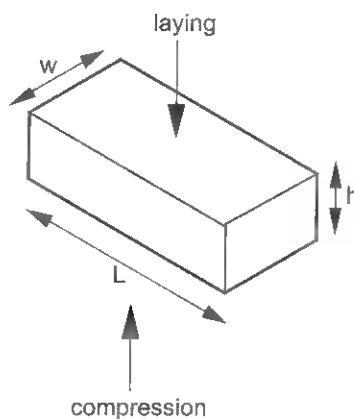
$$h = \frac{h_1 + h_2}{2} =$$

Volume of the block: $V = L \times w \times h$ (cm^3)

$V = $

MASS
Mass of the block = m (g)

$m = $

APPARENT DRY DENSITY
Density of the block = $\rho_d = \frac{m}{V}$ (g/cm^3)

$\rho_d = $

Compressed earth blocks : testing procedures

The following material has been specially prepared to promote compressed earth block technology amongst all who are involved in the building sector: governments, clients, national standards bodies, chambers of commerce, funders, technical endorsement companies, insurers, scientific and technical centres, laboratories, architectural and engineering practices, commercial enterprises, etc. It enables the impressive performances of the contemporary technology to be visualised in an eye-catching way.

EXHIBITION

Building with compressed earth blocks
CRATerre-EAG: Rigassi, V.
CDE, Brussels, Belgium, 1995.
110 x 75 cm. Colour, 23 panels.

This exhibition's large, exceptionally fine colour photographs and its concise, precise texts cover all aspects of the technology and give a spectacular demonstration of the contemporary performances of this material. It has already been shown on the occasion of industrial working seminars and international meetings in such cities as Lusaka, Libreville, Yaoundé, Brussels, Frankfurt, Grenoble, Bordeaux, etc.

The touring of the exhibition is organised by the CDE and CRATerre-EAG.

POSTER

Industrialised compressed earth block technology
CRATerre-EAG. Atelier Design.
CDE, Brussels, Belgium, 1996.
70 x 100 cm. Colour.

This poster, which was specially prepared on the occasion of the CDI/CDE seminar held in Yaoundé in April 1996 on the standardisation of compressed earth blocks, dramatically illustrates the current state of the art of compressed earth block production and industrial construction. It is aimed at all who are involved in the building industry.

Distributed by the CDE and CRATerre-EAG.

VIDEO

Compressed earth blocks
CRATerre-EAG, GTZ-GATE, UNIDO, DesignWrite Productions.
CRATerre-EAG, Grenoble, France, 1994.
VHS-PAL, 24 min, colour.

This video gives an overview of compressed earth block technology. After first placing earth once more in the historical context of architecture, this documentary shows uses of CEBs which are suited to modern building requirements, a range of different production machines, and examples of the current use of compressed earth blocks in various parts of the world.

Distributed by CRATerre-EAG/BASIN.

The following documents have been specially prepared so that together they form a coherent ensemble, enabling all the main stages of compressed earth block production, design and construction to be thoroughly understood.

EQUIPEMENT

Compressed earth blocks : production equipement
CDE Guide, "Technologies series" N°5
CRATerre: Houben H., Rigassi V., Garnier P.
CDE, Brussels, Belgium, 1996
210 x 297 mm, 149 pages, graph., ill., tab., bibl.
ISBN 2-906901-13-X

This guide, published by the CDI/CDE in its "Technologies series", is now in its third edition. It presents a complete and detailed inventory of compressed earth block production equipment manufactured and marketed in ACP and EU countries. It also contains selection criteria as well as technico-economic factors. The guide is an irreplaceable aid to decision-making on investment.
Distributed by the CDE and CRATerre-EAG.

STANDARDS

Compressed earth blocks: Standards
CDE Guides, "Technologies series" N° 11
CRATerre-EAG: Houben H., CDE: Boubekeur S.
CRATerre - EAG, Brussels / Villefontaine, Belgium / France, 1998.
210 x 297 mm, 142 pages, graph., ill., tab., bibl.
ISBN 2-906901-19-9

This guide puts forward a body of standards ratified as African Regional Standards which should henceforth enable planners to accept proposals from contractors and builders for the utilisation of compressed earth blocks.
The guide is also intended to be helpful in drawing up National Standards for compressed earth blocks.
Distributed by CDE and CRATerre - EAG.

PRODUCTION

Compressed earth blocks. Vol.1 : manual of production
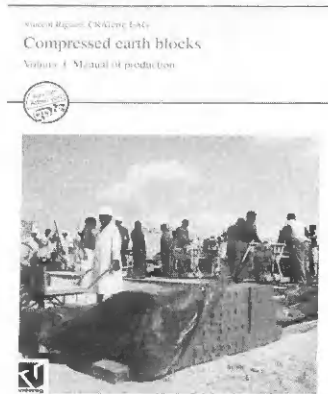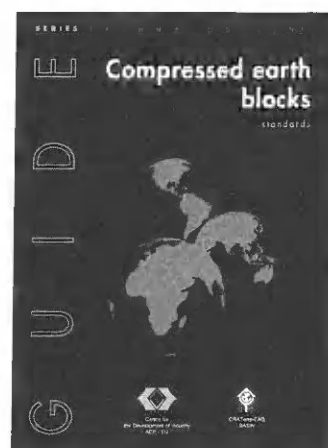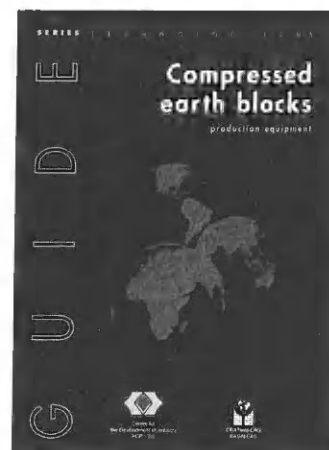CRATerre-EAG : Rigassi V.
Aus der Arbeit von GATE, Friedrich Vieweg & Sohn, Braunschweig/Wiesbaden, Germany, 1995.
210 x 297 mm, 104 pages, graph., ill., tab., bibl.
ISBN 3-528-02079-2

This manual provides decision-makers, designers, brick manufacturers and building entrepreneurs with the information they need on compressed earth block production. It is designed to enable an overall understanding of a production unit, as an aid to financial planning, and to help with the technical mastery of all stages of production.

Distributed by CRATerre-EAG/BASIN.

DESIGN AND CONSTRUCTION

Compressed earth blocks . Vol. 2 : manual of design and construction
CRATerre-EAG : Guillaud H., Joffroy Th., Odul P.
Aus der Arbeit von GATE, Friedrich Vieweg & Sohn, Braunschweig/Wiesbaden, Germany, 1995.
210 x 297 mm, 148 pages, graph., ill., tab., bibl.
ISBN 3-528-02079-6

This manual covers all theoretical and practical aspects of design and construction. A large part of the document is devoted to practical, finished examples. It provides answers to all the factual questions which field practitioners ask themselves, be they land use planners, architects, engineers, entrepreneurs or builders.

Distributed by CRATerre-EAG/BASIN.

BASIC INFORMATION

The basics of compressed earth blocks
CRATerre: d'Ornano S.
Aus der Arbeit von GATE, GTZ, Eschborn, Germany, 1991.
210 x 297 mm, 28 pages, ill.

This booklet lists advantages and constraints, briefly describes the production process and gives indications on the general approach operators wishing to launch an activity in the field of compressed earth blocks should follow; it also addresses some basic economic aspects.

Distributed by CRATerre-EAG/BASIN.

SCIENCE AND TECHNOLOGY

Earth construction: a comprehensive guide
CRATerre-EAG: Houben H. and Guillaud H.
IT Publications, London, United Kingdom, 1994
175 x 250 mm, 372 pages, graph., ill., tab., bibl.
ISBN 1-85339193-X

In the nature of an encyclopaedia, this book covers all aspects of contemporary earth construction technology. Each chapter summarises the most recent work on the subject. An indispensable aid for technicians, engineers and architects interested in or working in the field of earth construction.

Distributed by bookstores and CRATerre-EAG.

CASE STUDIES

Modernité de l'architecture de terre en Afrique. Réalisations des années 80
CRATerre : Guillaud H.
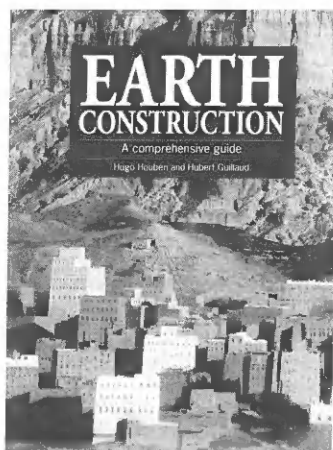CRATerre-EAG, Grenoble, France, 1990.
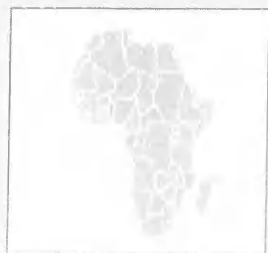160 x 240 mm, 177 pages, ill.
ISBN 2-906901-04-0

This book presents 14 exemplary projects from 6 different countries: Burundi, Mali, Morocco, Mayotte (Comoros), Rwanda, Somalia. The monographs cover a wide range of aspects including the building programme, the construction options, and construction costs, providing clear evidence that earth as a building material has succeeded in penetrating a very wide range of contemporary applications. (In French.)
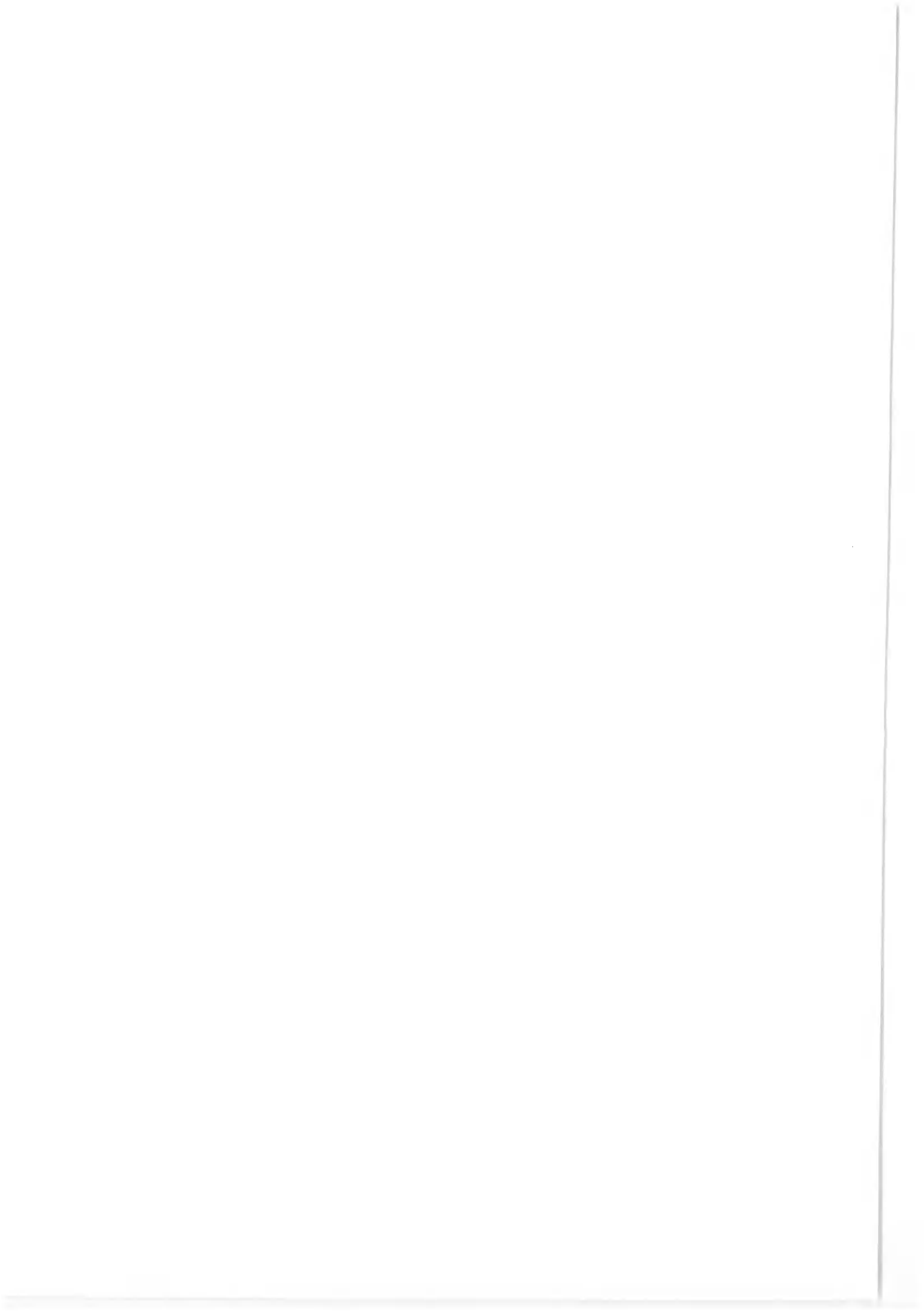
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As a result of their technical and economic performance, compressed earth blocks are increasingly in demand from building professionals in ACP countries. This is readily understandable because of the low level of investment their processing requires and their high potential for training and for job creation in the course of their production and use.

This guide forms part of the various activities to promote the CEB production and distribution chain which the CDI/CDE has been developing for some years with CRATerre-EAG. It is in fact the third publication devoted to this technology. The first (Guide N°5), distributed in 1988 and up-dated in 1996, addressed production equipment. The second (Guide N°11), which is closely linked to the present publication, relates to the Standards which were approved as African Regional Standards in October 1996 by the African Regional Standards Organisation (ARSO) to which 24 member states are affiliated.

These standards have had a definite impact and have become references facilitating exchanges and increasing confidence in this technology. The present guide describes the various test procedures for products or for raw materials and therefore enables one to check that performances conform to the standards. It is therefore vital for the application of CEB standards.

The guide is intended for all those who need to fully understand and assess product quality, whether they are responsible for producing, prescribing or using CEBs. The procedures described are applicable both by laboratories and by SME/SMIs, notably in introducing a quality or certification system. These procedures will facilitate exchanges between producers, laboratories, or technical centres, clients and contractors, and will enable them to guarantee the quality of their work to their end-users.

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